VOLUME 28 NUMBER 9

INDIANAPOLIS MEETING, MAY 28-31, 1907

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

MAY, 1907

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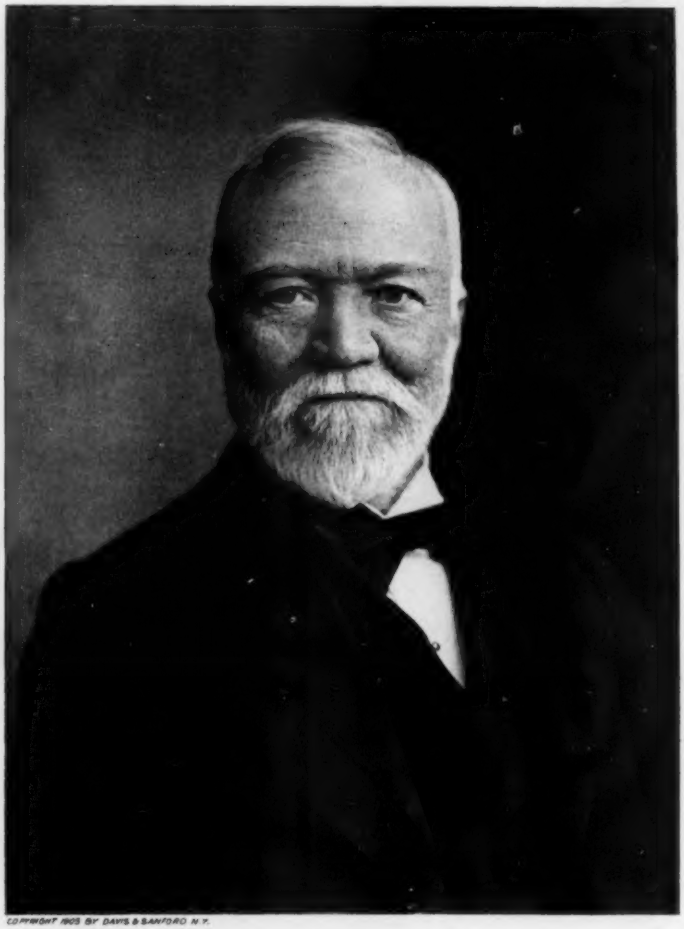

ANDREW CARNEGIE

HONORARY MEMBER

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

MAY, 1907 VOL. 28. No. 9

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 28 MAY, 1907 NUMBER 9

PROGRAM OF THE SPRING MEETING

THE Spring Meeting will be held in Indianapolis, Indiana, May 28-31. The headquarters room will be on the parlor floor of the Claypool Hotel, and the professional sessions on the top floor on the south side of the building. Seventy-five rooms have been reserved for Convention guests. Members who desire to have accommodations reserved should correspond with the hotel authorities at once.

The Local Committee in Indianapolis are preparing a booklet giving the different points of interest, the hotels, their names, rates, and locations, and also a map of the city. These books will be mailed to the membership about May 18.

A number of excursions to points of interest in and around Indianapolis have been arranged, and full information will be found in June Proceedings, which will appear about May 15.

The official headquarters will be opened in the Claypool Hotel at noon on Tuesday, May 28, and maintained throughout the meeting. Members and guests are requested to register as early as possible and to make this the occasion for turning in their railroad certificates.

OPENING SESSION

Tuesday evening, May 28, at 9 o'clock

In the Auditorium of the Claypool Hotel

Address of welcome. Response by Prof. Frederick Remson Hutton, President of the Society.

SOCIAL REUNION

An informal reception will be held after the opening address, which will give an opportunity for members and guests to meet and exchange greetings. Ladies will be especially welcome.

SECOND SESSION

Wednesday morning, May 29, 9.30 o'clock

Annual Business Meeting. Reports of the Tellers and Standing and Special Committees. New business can be presented at this Session.

Report of the Committee on Standard Proportions for Machine Screws.

Preliminary Report of the Committee on Refrigerating Machines.

"Collapsing Pressures of Lap-Welded Steel Tubes," Prof. Reid T. Stewart.

"The Balancing of Pumping Engines," A. F. Nagle.

"A Comparison of Long and Short Rotary Kilns," E. C. Soper.

Wednesday afternoon, May 29

Visits to various plants.

THIRD SESSION

Wednesday evening, 8.15 o'clock

AUTOMOBILE SYMPOSIUM

"Bearings and Moving Mechanism," Henry Hess.

"Air Cooling of Automobile Engines," John Wilkinson.

"Materials for Automobiles," Elwood Haynes.

"Special Auto Steel," T. J. Fay.

"Railway Motor Car," B. D. Gray.

FOURTH SESSION

Thursday morning, May 30, 9 o'clock

SUPERHEATED STEAM

"The Specific Heat of Superheated Steam," A. R. Dodge.

"The Flow of Superheated Steam in Pipes," E. H. Foster.

"Co-relation of Furnace and Superheated Conditions," R. P. Bolton.

"Valves and Fittings for Superheated Steam," J. H. Berryman.

"Use of Superheated Steam on Locomotives in America," H. H. Vaughan.

EXCURSION

Thursday afternoon, May 30

RECEPTION

Thursday evening, May 30, 9 o'clock

FIFTH SESSION

Friday morning and afternoon, May 31

EXCURSION TO PURDUE UNIVERSITY, LAFAYETTE, IND.

A Professional session will be held at 10 a. m. in one of the University buildings.

"Performance of Cole Superheaters," W. F. M. Goss.

"Experiences with Superheated Steam," G. H. Barrus.

"Superheated Steam in an Injector," S. L. Kneass.

"Determination of Entropy Lines for Superheated Steam," A. M. Greene.

"The Heating of Store Houses," H. O. Lacount.

Other papers expected but as they have not yet been received from the authors they are not listed in the program.

INDIANAPOLIS NOTES

The University of Illinois extends to the Members of the Society attending the Convention in Indianapolis a cordial invitation to visit the University where they will be received by Dr. L. P. Breckenridge, Professor of Mechanical Engineering, and Director of the Government Research Station. Those who take advantage of this invitation will find the trip to Urbana very pleasant and profitable.

RAILWAY TRANSPORTATION NOTICE

INSTRUCTIONS FOR THE PURPOSE OF RAILWAY TICKETS AND IN REGARD TO SPECIAL CARS, ETC., FOR THOSE ATTENDING THE SPRING MEETING AT INDIANAPOLIS, MAY 28-31

Owing to the enactment of two cent fare laws by the legislatures of a number of States in the territory included under the jurisdiction of the Central Passenger Association, and by reason of these material reductions in their passenger revenue, the transportation lines in this Association are compelled to modify the arrangements they have made for many years for convention travel.

The Central Passenger Association, in whose territory Indianapolis is located, announce a rate of two cents per mile in each direction from points in their territory. Tickets of signature form will be sold on May 27, 28 and 29 and will be good for return to leave Indianapolis to and including, but not later than June 1. Provision will be made for the validation of these tickets at the Indianapolis ticket office. This Association comprises the following territory:

The portion of Illinois south of a line from Chicago through Burlington to Keokuk and east of the Mississippi River, the states of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lake Michigan and Huron.

The Trans-Continental Passenger Association announce one first class thirty day fare for the round trip from California, for instance, to Chicago and return $72.50, to St. Louis and return $67.50. These tickets are on sale on two days only, May 20 and 21, and may be purchased, going via any regular direct route, returning via the same or any other regular direct route. Stop-overs will be allowed between the California line and Chicago. The purchaser must reach his destination within 10 days of date of sale. Tickets are good for return within 90 days of date of sale. This Association also announces the regular nine months rates to Chicago and St. Louis; these approximate two cents per mile in each direction, or about one fare and one-third for the round trip. The territory includes California, Nevada, Oregon, Washington and west of and including Mission Junction,

B. C., including also Kootenay common points, Nelson, Rossland, Sandon, Caslo and Grand Forks, B. C.

The Trunk Line Association at the time of writing declines to grant the fare and a third rate for the round trip. They quote the regular fare, $18.50 each way from New York City. This Association includes the following territory:

All of New York, east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia, north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville and Washington, D. C.

Arrangements for transportation, sleeping car and hotel accommodations, should be made personally by each person attending the meeting.

Members from the East wishing to return via Washington may do so without extra charge by securing tickets marked "via Washington." These tickets will be good for a trip either via Washington or by the more direct route. They are good for a ten day stop over in Washington.

SPECIAL TRAIN ARRANGEMENTS

FROM NEW YORK AND OTHER PENNSYLVANIA RAILROAD POINTS EAST

One or more private Pullman sleeping cars will be reserved on each of two trains from the East. These reservations will be made only in case the number of applications received for Pullman accommodations reach the minimum set by the company.

The first train selected is the "St. Louis Express" which will leave New York on Monday and arrive in Indianapolis during the afternoon on Tuesday. The first session of the meeting will be on Tuesday evening. The schedule for this train will be as follows:

Lv.	New York, Monday, May 27	6.25 p. m.
"	Philadelphia	8.58 p. m.
"	Pittsburg	5.37 p. m.
Ar.	Indianapolis, Tuesday, May 28	3.05 p. m.

The second train selected is the "Pennsylvania Limited," leaving New York on Tuesday and arriving in Indianapolis on Wednesday in time for the first professional session. New York members going by this train can have two hours in their offices on Tuesday.

Lv.	New York, Tuesday, May 28	10.55 a. m.
"	Philadelphia	11.10 p. m.
"	Pittsburg	8.55 p. m.
Ar.	Indianapolis, Wednesday	6.55 a. m.

FROM CHICAGO

The train out of Chicago via "Big Four" upon which a special car will be run if the number of reservations warrants it, will reach Indianapolis in time for the opening session Tuesday evening. It is believed that our members and their guests will be glad to coöperate to secure this additional opportunity for social intercourse with old friends. The schedule will be:

Lv. Chicago, Tuesday, May 28	1.00 p. m.
Ar. Indianapolis	6.20 p. m.

PROGRAM

First Day, Tuesday, April 16, 1907

DEDICATORY EXERCISES

At 3 P.M.

Music. Largo, Handel. The Richard Arnold Double Sextette.

Opening by Charles Wallace Hunt, Past President A. S. M. E., Presiding Officer. The first use as a gavel of the setting maul employed by Mrs. Carnegie in laying the corner stone of the building.

Prayer by Rev. Edward Everett Hale, D.D., Chaplain U. S. Senate.

Communications from The President of the United States; The President of the Republic of Mexico; The Governor General of Canada.

Historical Address by Charles F. Scott, Chairman of the Building Committee.

Acceptance of the Building by E. E. Olcott, President of the United Engineering Society, representing Founder Societies.

Address by Andrew Carnegie, Donor of the Building.

Music. Traumerei, Schumann. Cello Solo, Kronold.

Oration by Arthur T. Hadley President of Yale University, "The Professional Ideals of the Twentieth Century."

Music. Hallelujah Chorus, Händel.

Formal Dedication of Building.

Adjournment.

RECEPTION

9:00 P. M TO 10:30 P. M.—General Reception in the Main Auditorium.

10:00 P. M.—Reception by the Officers and Councils of the Founder Societies in their respective Headquarters.

The American Institute of Mining Engineers—Ninth floor
The American Institute of Electrical Engineers—Tenth floor
The American Society of Mechanical Engineers—Eleventh floor

Refreshments will be served during the evening on the fifth floor. Music on Main Auditorium, Fifth and Library floors.

Second Day, Wednesday, April 17, 1907

DEDICATORY EXERCISES

At 2.30 P. M.

Introduction by John W. Lieb, Jr., Chairman of Dedication Committee.

Addresses by Presidents of Founder Societies:
Samuel Sheldon, President, American Institute Electrical Engineers.
F. R. Hutton, President, American Society Mechanical Engineers.
John Hays Hammond, President American Institute Mining Engineers.
T. C. Martin, President The Engineers' Club.

Greetings and Felicitations from Foreign and National Scientific Societies and Institutions of Learning.

Address by James Douglas, Past President American Institution Mining Engineers

Presentation of the John Fritz Gold Medal to Alex. Graham Bell, past President American Institute Electrical Engineers. (By Charles F. Scott, Chairman John Fritz Medal Board of Award.)

Presentation of Commemorative Medals for Distinguished Services to: R. W. Pope, Secretary, A. I. E. E.; F. R. Hutton, Past Secretary, A. S. M. E.; Rossiter W. Raymond, Secretary, A. I. M. E. (By A. R. Ledoux, Past President, A. I. M. E., representing the three Societies.)

PROFESSIONAL SESSIONS OF FOUNDER SOCIETIES

Monday, April 15, 8.15 P. M.

Special meeting in Main Auditorium of the American Institute of Electrical Engineers presided over by Sir W. H. Preece, K. C. B., F. R. S., past President and Representative of the Institution of Electrical Engineers of Great Britain.

Paper by Louis M. Potts on the Rowland Telegraphic System and its Apparatus.

Thursday, April 18, 2 P. M.

Meeting of the American Institute of Mining Engineers in the Main Auditorium.

Illustrated paper by H. T. Hildage on Mining Engineering Operations in New

York City and vicinity descriptive of the Excavation and Tunnel work now in Progress in Greater New York.

Thursday, April 18, 8 P. M.

Meeting of the American Society of Mechanical Engineers in the Main Auditorium. Paper by Brig. Gen. W. Crozier, U. S. A. on the Ordnance Department as an Engineering Organization.

Friday, April 19, 8 P. M.

Informal Smoker and Vaudeville, Madison Square Garden Concert Hall, under the management of The American Institute of Mining Engineers for the members of the three Founder Societies.

All Engineers visiting or residing in New York are cordially invited to participate in these special exercises of the Founder Societies during Dedication Week.

Full programs have been issued by each Society as to its special functions of the week.

DEDICATORY EXERCISES

The Dedication of the Engineering Societies Building

The opening exercise of the Dedication of the Engineering Societies Building was held in the Auditorium on Tuesday afternoon, April 16, with Mr. Charles Wallace Hunt as Presiding Officer. The distinguished guests who addressed the audience were Rev. Edward Everett Hale, Andrew Carnegie, and Arthur Twining Hadley. Richard Arnold's Double Sextette rendered Handel's "Largo," after which the Presiding Officer opened the meeting.

Mr. Hunt. On the eighth of May, 1906, Mrs. Andrew Carnegie laid the corner stone of this building. She has graciously presented to the Engineering Society this Setting Maul that was used by her on that occasion. The historic event in which this implement has taken a part, and Mrs. Carnegie's graceful act in placing it henceforth in our care, makes it an especially precious object to us. It will henceforth be used by the presiding officer of the meetings held in this auditorium. As a gavel, its voice will now be heard for the first time in calling this dedicatory meeting to order. [Sound of the gavel.] Prayer will now be offered by Rev. Edward Everett Hale, D.D., Chaplain United States Senate.

PRAYER

Most Worshipful God, thou who hast given us of thine own Holy Spirit and hast given us inspiration that we may come and go in thy work and live for thy glory to accomplish thy purposes, and best of all, hast shown us that thou art indeed the Father and we the children of thy love, we thank thee that we are the partakers of the Divine Nature, if we will, and first, second and last, we must go about our Father's business.

Thou hast been pleased to smile upon the endeavors of those who have raised this temple to thine honor, and for the good of man and the glory of God; thou hast taught them how to control time and space; thou hast taught them how to leap forward and upward to the light and knowledge of thee, which shall bring them into the ways of closer relationship with God with the beginning of every new day.

We praise thee that thou hast placed the materials and thy power in the hands of those children that they may conquer every obstacle and that they may draw men closer and closer to each other and make them to know more and more of the Father. Bless them in those days that are before them, and join them together even as the Father unites the children of one household, so that they may be allied with the Spirit of the living God and that they may know what thy purpose is for this world.

We ask that thou will bind together the nations of the world; that thou will bind together thy sons for the betterment of the world, so that each may bear his brother's burden and so fulfil the holy law of Christ.

Grant us this in thy Holy Spirit, we ask it in the name of Him who taught us to pray:

Our Father which art in heaven, Hallowed be thy name, Thy kingdom come. Thy will be done in earth, as it is in Heaven. Give us this day our daily bread. And forgive us our trespasses as we forgive those who trespass against us. Lead us not into temptation, but deliver us from evil; For thine is the kingdom and the Power, and the Glory forever. Amen.

CONGRATULATORY MESSAGES

The following message from the President of the United States was read by Mr. T. C. Martin.

THE WHITE HOUSE
WASHINGTON, D. C., *April 13, 1907*

THE UNITED ENGINEERING SOCIETY:

I heartily congratulate you on the opening of the building of the Engineering Societies. The building will be the largest engineering center of its kind in the world. It is indeed the first of its kind, and its erection in New York serves to mark and emphasize the supremacy which this country is steadily achieving through her proficiency in applied science. The whole country is interested in the erection of such a building, and particularly of course all of those who follow either the profession of engineering or any kindred profession; and in no branch of work have Americans shown to greater advantage what we like to think of as the typically American characteristics.

With all good wishes, believe me,

Sincerely yours
THEODORE ROOSEVELT

MR. MARTIN Ambassador Creel of Mexico presents in person the congratulations of the President of his Republic.

AMBASSADOR CREEL It is one of the great honors of my life to be present at the dedication of the Engineering Societies building and

I have the privilege of offering to you a message from the President of the Republic of Mexico, General Diaz, whom I have the honor to represent.

MEXICO CITY, MEXICO, *April 13, 1907*

THE UNITED ENGINEERING SOCIETY:

In reply to the telegram in which you ask me to be present at the dedication of the building donated by Mr. Carnegie for the Engineering Societies, or to express my sentiments concerning that event so worthy of celebration, it not being possible for me to be present, I would express my cordial good wishes for the engineers who contribute so much to the development and welfare of humanity; and my admiration for the great philanthropist, Andrew Carnegie, whose splendid generosity is known by the entire civilized world.

PORFIRIO DIAZ
President of the Republic of Mexico

MR. MARTIN Earl Gray, the Governor General of the Dominion of Canada, was unfortunately detained by a delayed train, and sent a message of congratulation and good wishes to Mr. Carnegie and his audience.

The Dean of the engineering profession in America, Charles H. Haswell, now in his ninety-seventh year, expected to be present but a letter was received from him in which he expressed his regret that illness detains him at home, and requested that this excuse be submitted to his much honored friend, Andrew Carnegie.

HISTORICAL

MR. HUNT There have been several prior attempts to bring the national engineering societies into closer fraternal relations, but each was without a tangible result. In December, 1902, Charles F. Scott, then President of the American Institute of Electrical Engineers in a public address happily voiced the aspirations and the hopes of the progressive engineers who had so long worked in various ways toward a common end. He pictured before his audience, a magnificent building, the "Capitol of American Engineering." Into this home, situated in the metropolis of the nation, are gathered the great engineering societies from their scattered lodgings.

In his vision, he there saw a great technical library; ample assembly halls; comfortable parlors; and, also, the headquarters of a score of lesser societies, restricted in their scope but affiliated in their work.

Two months later, a dinner to celebrate the founding of the American Institute of Electrical Engineers, was arranged under the guiding hands of Mr. T. C. Martin and Mr. Calvin W. Rice. Mr. Andrew Carnegie after having four times refused Mr. Martin's invitation accepted the fifth and attended the banquet on February 9, 1903. At

this meeting was voiced again the oft expressed wish that the national engineering societies would join hands to the end of creating a great technical library, doing coöperative society work, and having suitable headquarters that would furnish ample accommodation for themselves and for many kindred societies.

Mr. Carnegie was an interested listener to those addresses. His interest was not impulsive or ephemeral, for the next day he wrote to Mr. Rice asking him to call with a friend for a conference on the subject matter of a union engineering building. This conference was attended by Mr. Charles F. Scott, President, and Calvin W. Rice, a Director of the American Institute of Electrical Engineers.

The events following this fruitful conference will now be presented to you by Mr. Scott, who has been the tireless chairman of the joint Conference and Building Committee from its organization four years ago to the present time. This large Committee with its nearly one hundred regular meetings, and the expenditure of one and a half million dollars in this movement, came to a full agreement on every subject, important or trivial, and for the entire four years adopted every resolution by a unanimous vote.

I present Mr. Charles F. Scott.

Mr. Charles F. Scott The realization of the ideals of many years and the definite beginning of the building which we today dedicate dates back four years. On February 10, 1903, Mr. Carnegie talked over the project with the two gentlemen whom he had invited to his house. As the general scheme seemed feasible, he said that he was ready to provide the funds for a building if a practicable plan could be presented. An hour later, a meeting of engineers had been arranged for the following day. The scheme was discussed; plans were formulated, and a few days later John Fritz, John C. Kafer, William A. Redding, Calvin W. Rice, Charles F. Scott and John Thompson discussed the matter freely with Mr. Carnegie. To these gentlemen, on St. Valentine's Day in the late afternoon, he said the magic words which transformed long cherished dreams and new found hopes into a reality.

And here about us is the culmination; the work of committee, and architects, and builders. The building stands as its own record of what has been done. The result is simple and easily seen; yet, it embodies the solution of many problems. At first it seemed that so much was achieved when the funds were provided that little remained to be done. But much has intervened between the making of the gift and completing of the building.

In designing the building we had no precedent to follow, for never before had engineering found so generous a patron. Engineering societies themselves belong to the new order of things. The oldest of the participating societies numbered little more than three decades. In the past these societies were well nigh strangers to one another. Now to utilize this gift they must plan and work together. The gift, moreover, had a unique feature in being presented in common to professional societies, whose interests are technical, and to the Engineers' Club, which is social.

At the beginning there were broad questions of general policy to be determined. There must be a basis of relationship between the professional societies, and then one between the societies and the social club. As the outcome of this first step, three members from each of the three societies, and three from the club, were appointed as a conference committee of twelve members. Through its subcommittees, the two buildings with convenient inter-communication, have been erected on land acquired, respectively, by the societies acting through the United Engineering Society, and by the Club.

The building for the engineering societies required first of all to be planned in imagination. What were the immediate needs of our three societies? How many associate societies would join us, and what were their needs? What should be the size and number of assembly halls; the provision for offices, for board rooms, and reception rooms and library? Even though we gaged the present accurately, how should we estimate the future needs? What of the future growth? So rapid is the present growth that the aggregate membership of the three Founder Societies has increased 53 per cent since the gift was made. New engineering societies are being formed.

It would be interesting to relate, if time permitted, how our ideas developed, so that a million dollars was too little, and Mr. Carnegie graciously made his letter read, "say, a million and a half;" how our ideas crystallized into a program to be followed by competing architects; how we selected from 26 sets of plans the one which all agreed was best; how we studied the details of arrangement and the selection of materials to secure flexibility in the functions of the various parts of the building, and to insure a wise expenditure of the funds entrusted to us; and how efficiently architects and builders have done their part.

We recognized that the underlying purpose of Mr. Carnegie was to develop the human as well as the technical side of the engineering profession. He said to us that coöperation is "the keynote of success," and that there is "a harmonizing feature which counts for

everything in the progress of any great movement, political, social, or scientific." Hence he associated together the club and the societies in order, as he expressed it, "to combine the social with the scientific."

The same idea has guided the arrangements of the societies' building. It is seen in the reception rooms of the societies, in the spacious entrance hall, in the corridors about the auditorium, in the arrangement of the smaller halls, by which the one used as a lecture room may have an adjoining one as reception room, and in the provision for serving light refreshments, which add zest to the social after-meeting.

And then, in a sense, the crowning feature of the whole project, as it is of the building itself, is the Library. In the magnificent spaces which are above us there lies a great possibility. The libraries of the three societies are the nucleus, the foundation, for a great engineering library, a depository for archives, a record of experience and achievement, a storehouse of intellectual power of countless value and far reaching influence. In the future it may be embellished and dignified by memorials of those who have contributed to the engineering progress of the world. In this library, the past officers of the societies have already placed a bronze bust of the donor as a perpetual recognition of the great gift of this building.

And this building—simple, dignified and appropriate to its intended uses—is to be the home of the engineering societies.

These societies are the expression of engineering forces, and engineering forces are fundamental to the achievements of our age.

Underlying the tremendous economic changes of the present times is the power generating steam engine. Driving the locomotive, it has transformed innumerable provincial towns into one great community, and many independent states into one nation. Driving the factory, it has developed manufacturing and industry on a scale undreamed of a century ago, and scarcely comprehended now. Driving the ocean vessel, it is rapidly making the whole world kin.

Its influence transforms and vitalizes. The present production of wealth, the new function of capital and labor, the modern business corporation, the occupations and social relations of men, the growing brotherhood which portends a universal peace—all have followed the engine of Watt, all belong to the new epoch, the epoch of manufactured power.

The whole fabric of our daily life is based upon the modern methods of utilizing the materials and forces of nature; it is reared upon foundations laid by the engineer; it daily depends upon the opera-

tions which he controls. He has been the harbinger of prosperity and of peace.

And the end is not yet. Progress continues at an accelerating rate. See what electricity has accomplished within our easy recollection, yet we scarcely realize it unless for even a single day we have no telephone, no electric light, no street car. The growth of the telephone in its first ten years is exceeded by the present growth of a single year; the output of all electric central stations at the end of the first ten years is exceeded by that of many a single station today.

But I am merely repeating what we all know. I simply ask you to realize that the engineer has been foremost in bringing about our present civilization, and that to him new and larger problems are continually presented. Not only does the quantity and the difficulty of his work increase, but it even promises to be of a new quality. With the twentieth century there begins a "new knowledge," in science; from it there may soon follow a new engineering.

These increasing responsibilities demand that the most efficient methods be found. The characteristic of the modern method of large accomplishment is coöperation, by which men act not as individuals but in concert. Years ago each engineer was apt to work by himself; technical knowledge and experience were kept secret. Stagnation resulted. Through intercourse of knowledge and interchange of experience, progress came, and in those branches where discussion has been active, progress has been most rapid.

The engineering society has become the clearing house for knowledge and experience. And herein is the great purpose of this building. It is now the instrument of coöperation among engineers. It enables these societies to become more useful in the dissemination of knowledge, in the training and development of men, in the cultivation of high ideals, and in making the engineering profession more efficient in its great task of making this world a better place to live in.

The significance of this building is not in the past, nor in the present, but in the future; for the vitality which has prompted engineering development in the past is unabated now and will continue with increasing force in the future. Witness this event—a gift of a million and a half for buildings, supplemented by a half million more—the largest investment for engineering in the history of the world—and this audience of a thousand men, representative of science, engineering, education, literature, art, and government, gathered with sympathy and joy to bid Godspeed to the work we here inaugurate—and acclaim this day the beginning of a new era in engineering.

Mr. Carnegie, it has been your great privilege to make this possible.

You provided money; it has been transformed into bricks and mortar. But your letter gives more than money—in it is an Ideal, "a *union* building for *you all;*" that, too, has transforming power; already the "harmonizing feature" is an active force, our societies are working together; they are getting a broader view of their position and new inspiration for the large work which lies before them.

As we were leaving your house on the day you made the gift, Mr. Fritz lingered a moment. When he overtook me he told me that he had said to you, "Mr. Carnegie, the day will come when this gift will be looked upon as one of the wisest and most useful that you have ever made." And I am sure I voice the sentiment of this audience when I say that John Fritz was right.

DELIVERING THE KEY OF THE BUILDING

MR. HUNT To the architects we are indebted for the architectural beauty of this monument to engineering. To their ability in grasping the desires of the Committee and their skill in working them into a harmonious building, both within and without, the whole engineering profession are their debtors.

Under their skillful guidance this edifice has been erected within the amount of funds first assigned for the purpose, and occupancy commenced a few weeks after the builders' contract time had expired.

It is now a pleasure to be able to state that in the design and in the erection of this building, no difficulties have arisen between the committee and its architects or the builders, and no compromises or makeshifts of any character have been made in the execution of the work.

And now, Mr. Olcott, acting in behalf of the Founder Societies, this building is placed under the administration of yourself and of your successors. [Giving the key to E. E. Olcott, President of the Trustees of the United Engineering Society.]

This gift to engineering, which we now dedicate, is not only, or even principally, the presentation to the Societies of this material building. Immeasurable benefits will also flow from the orienting of the minds and directing the energies of engineers into more effective coöperative work.

We confidently trust that under your fostering care the Library will develop into one of world wide influence, and be as an ever helping hand, freely extended to any person who seeks help from the experience of those who have gone before.

We have an abiding faith that it is not engineers alone that will be benefited, but that the world itself is a better abode for man

because of Mr. Carnegie's great donation. We fondly hope that this home of engineering under your guardianship will ever be freely open to whatever will bring purer aspirations, nobler ideals, or more fruitful lives to the generations of men who will come after us.

Mr. E. E. Olcott It seems to me, Mr. Chairman, as though this key with which you honor me, as President of the Trustees of the United Engineering Society, were the key of the whole engineering situation. It is suspended by the red, the white and the blue, a color for each of the three Founder Societies, and the three together forming a perfect union fittingly representing all the associate societies and standing for the engineering profession. May these all, without any loss of individuality nevertheless, form a grand enduring whole which shall typify the national federation of our states, and may our individual engineers shine as do the stars on the blue field of our country's emblem. In this union, there is strength. Depending on my own wisdom, it would be impossible faithfully to carry out the duties implied, and I could not attempt it but for the strength of the phalanx of United Engineering. This key opens the great bronze doors of knowledge, of usefulness, and of accomplishment, and the building thus opened and dedicated is one of the world's greatest storehouses of the records of engineering achievement. It shall be the trysting place of the guilds that plan the physical progress of the world. The great Library which crowns it is already one of the most complete technical libraries in existence, especially along mechanical, mining, and electrical lines. When we can secure an adequate endowment, it will become even more important. It is happily situated within a stone's throw of the new Public Library, which it is bound to supplement on engineering subjects. It is open for the benefit of mankind. This key stands then for freedom, coöperation, and the open door. With it we can unlock some of Nature's hidden secrets. The currents of electricity have played around the world for all time, but only recently has the engineer harnessed them in the service of man. The iron ores have been in the "everlasting hills" since the creation, but only recently has the engineer been able to fashion the steel into the mammoth structures—the bridges, the railways, and the tunnels.

The engineer should be the altruist, content to seek not so much his own as the world's achievement. We cherish then the gift of the benefactor—a man whose very fortune is an exponent of "United Engineering," and whose gift to us most truly embodies the man's own life, and perfectly supplements in this metropolis, his great institute dedicated last week at Pittsburg. Neither he nor we can

live to see the good that this building will do, emphasizing as it does, the strength there is in unity, by which thorough coöperation and the publication of the results of scientific research we are helping to advance the progress of the world.

In all Latin countries the key has the most sentimental significance, typifying the love of the man for the woman of his heart. What engineer worthy of the name has not as much love for his profession as for his sweetheart. And so, Mr. Chairman, in the name of United Engineering, with this key as a token, "we plight thee our troth," and pledge that so much as in us lies, we will carry out the ideals of the munificent donor and all who have contributed towards the liquidation of our mortgage indebtedness for the land on which this noble pile has been erected.

Mr. Hunt At an early conference with Mr. Carnegie, the business in hand being disposed of, the members of the committee, as they were preparing to leave, were conversing with him on various subjects foreign to the occasion of their visit. Mr. Carnegie mentioned his lively interest in the project of erecting a modest memorial to James Watt. In closing he remarked: "I do not believe in expending large sums on monuments," then turning a little aside from his guests, he threw his left arm caressingly around an imaginary object, and pointing to it said in a low soliloquizing tone—"What I *do* believe in is something with a living soul in it."

This chance remark deeply impressed his auditors. "Something with a living soul in it," seemed to them more than a building; more than rooms without rental. In imagination they saw a grand engineering building, and dwelling within it an ever living soul of helpfulness to us and to our successors. In their vision, they saw this living soul developed into a potent world force, constantly working as the centuries pass, for the elevating of everything in our civilization that depends on the life and the work of the engineer.

To make this fleeting thought a reality, and develop the idea into an ever living soul, the Committee would have to undertake a task far greater than the erection of a building. It would be the erection of a building, plus the embodiment of this vision. Instead of a gratuity to a few societies, it would become a gift by Mr. Carnegie to engineering in its broadest sense. Unanimously the Committee adopted this broad view and diligently bent its energies to work out the double task, as the way opened.

The Committee has terminated its labors and now presents this building as a worthy home for that "living soul" whose contempla-

tion animated the mind of its donor and inspired the recipients of this great gift.

I present Mr. Andrew Carnegie, donor of the building.

ADDRESS BY MR. CARNEGIE

Mr. President, Mr. ex-President, Mr. Present President, and Uncle John Fritz:

The Scotch have a saying, and they have many wise sayings, that fools and bairns should never see a thing half done. I don't wish to associate myself either with fools or bairns, but I think I may add that donors should never see a thing half done. I went to Pittsburg the other day knowing nothing of what I should find; I had sedulously kept away from the fairy palace that they were erecting; I knew nothing of it, but when I got there I found a palace that Alladin might have brought forth and so beautiful that I felt that I was in a dream. I come here today under somewhat similar circumstances, and am brought into this beautiful hall, exquisite in every part, and face to face with this splendid audience. Well, it gives point to what Mrs. Carnegie said when I was expressing to her that I was totally unable to realize what part I had taken in creating a palace; I said to her I felt like Alladin rubbing the lamp, and she said, "Yes, and we didn't even have to rub the lamp." But as the proceedings went on at Pittsburg and I had the great pleasure of addressing those there present and showing the audience who had created the palace, this thought occurred to me: It is the spirit with which men are enthused that does the work; the sense of coöperation and the realization of the performance of great and benevolent work who raises the men who participate in it far beyond any personal work for themselves. The safety of human society lies just here. Whenever men coalesce to do some good, a unification takes place and a consolidation; and whenever men meet to conspire against the public good to do some evil, they find themselves unable to trust each other. Segregation takes place and they fail. That is the reason why you needn't lie awake nights and worry about the future and about what problem society is going to meet. As sure as the sunflower turns toward the sun and receives its light and heat just as surely human beings march onward and upward with their faces to the sky to do better things. Much that I was taught in my youth has passed away; much that I once thought of I have had to discard; but here is the rock upon which I rest and meditate and find happiness. Nor can you deny this, that quite apart from whatever evil exists there is

that principle of improvement inherent in us. Today is better than yesterday, and tomorrow will be better than today. So I look forward to the future of this building, and I know that the organizations to whom it is devoted will advance and continue to meet the developing needs of the age as the years roll by. That is comforting, that is encouraging, and that is a reflection to which I shall always return and upon which and in which I shall always find rest.

I congratulate you upon your architects. This architectural selection was just in accordance with my ideas. I have never given a building in my life that I could control except by competition; I don't want names of architects, I don't want everything that an architect may present, for human Homer nods and the dead past nods even; I want to see what a man brings and I don't want to see what his name is or to know his name. There were 26 plans submitted, as you have been told, and there was a committee to pass upon them, and then there was a very wise and good man as a sort of censor over the plans, Professor Ware, and he chose two plans—one for the Engineers' Club Building and the other for this building as being the best, and, by the way, the Committee had previously agreed upon those two plans. Well, who were the architects—some well-known great firm? No; they were two young men that had never been heard of in New York, I think. There is the proud father of one of them [here Mr. Carnegie turned to Dr. Edward Everett Hale and bowed], and there is a lady sitting up there [pointing to Mrs. Carnegie, who sat in the balcony] who is also proud, for the other successful architect was Mrs. Carnegie's brother.

Well, gentlemen, that is triumphant democracy. No pedigrees, no social influence count for much in the architectural profession. Nothing but real merit. And with the engineers who act it shows you that they were true to the principles of their profession. The engineer works from morning until night unvaryingly for what is true. Two and two make four and one five all the time. That gives the engineer his character. No fraud, no deviation, no evasion, but march, march, march, true to the line all the time.

I wish to speak of one remark that The President makes about American characteristics, and you also, Mr. Chairman, have spoken of my reference to the spirit of union in coöperation. One of the great advantages which the American has over the man of any other country lies in his ability and in his disposition for coöperation. Our political institutions which make every man the peer of any other man, every man's privilege any other man's right, lies at the foundation of that characteristic. Americans all meet upon a plane

of equality; what one man has is just as good as another man's and therein he meets in a sense of brotherhood, and the committees that you hear about acting by a "unanimous vote" is the outcome of this. I venture to say there never was such a case with the Britons or the Scotch, especially with the Scotchmen.

"Where are you going, Sandy?" said one Scotchman to another.

"Doon to the club," said Sandy.

"An' wha' foor?"

"Just to contradeect a wee."

That is the way it is over there.

Now, the American with his political institutions, with the blending that he has in him of all nations, is a man who partakes of the best quality of each of the other nations. It is from this fact that you find coöperation, and I speak with great experience knowing manufacturers and engineering societies on the other side, every one of them standing apart and unable to get together, and here the American calmly sits down and discusses and coöperates and evolves. If there are any guests here from the other side—yes, I see there is one [pointing to Sir William H. Preece]—I think he will carry home with him from what he heard in Pittsburg—for there was a similar story—there—this impression, and that he will say, "Well, these Americans begin even in business to feel more of the spirit of brotherhood than we do."

That we only hate those whom we do not know is quite true. That is my experience. The older I get—no, I mean the younger—and the more experience I have with men and with women, the more I am convinced of the truth of the fact that you only have to know the virtues of your fellow men to find that they are all brothers. That is the reason that I am a great advocate of the peace of the world. It isn't enough for individuals to feel the spirit of brotherhood as all Americans do, but we must enlarge it and realize the great truth that all men of all nations are really our brothers.

I have no more to say to you than to express my surprise again that the little conversation that Uncle John Fritz and these gentlemen and myself had has resulted in such a magnificent building as this, and more than that, with proving to the world that the Engineering Societies of America are one band of brothers with headquarters here to which every one of them is loyal. I thank you very much.

Mr. Hunt This twentieth century promises to exceed all preceding ones in the rapid, almost tumultuous, advance in the arts and sciences. Engineers are largely engrossed in the investigation of

specific problems and in the constructive work of this great stream of progress. There are, however, gifted persons in this century's work, who have raised themselves to an elevated position, on a mountain top, as it were, from which they can clearly survey this great field of action. With trained intellect and quickened perceptions they can bring us to tidings of surpassing interest as to whitherward we are traveling.

We count ourselves especially fortunate in having the privilege of hearing, as orator of the day, one whose exalted position gives him a clear view of the whole field of human endeavor. Your Chairman presents Arthur T. Hadley, President of Yale University.

THE PROFESSIONAL IDEALS OF THE TWENTIETH CENTURY

ARTHUR TWINING HADLEY A building like this is the best monument of what the twentieth century has accomplished.

The really important part of the history of a nation is the development of its ideals and standards. The specific things that it does are important not so much for their own sake, but for the sake of the evidence they give as to the trend of a nation's thought. It is not the magnitude of the individual battles which makes a war worth reading about. It is the ideas under which the war is conducted and the constitutional principles for which it is fought. It is not the census figures which decide whether a nation is great or small. It is the industrial methods and educational ideas which these census figures indicate. And in like manner it is not the buildings and machines and railroads and mines which constitute the important part of the history of the engineering profession. A book might give a good description of a thousand of these great engineering works, and yet fail of being in any sense a true history of engineering progress. The thought of the successive builders and the influence of that thought upon the conduct and ideals of other men are the things that we really care about. The story of the concrete achievements that have dazzled the eye of the world is but the unimportant and superficial part of the history. The real thing for which we care, the thing that helps us to understand the past and inspires us with hope for the future, is the story of the men who did the things—their struggles and their discoveries, their trials and their successes.

The men who did more than anyone else to make the nineteenth century different from the other centuries that went before it were its engineers. Down to the close of the eighteenth century the thinking of the country was dominated by its theologians, its jurists and its physicians. These were by tradition the learned professions;

the callings in which profound thought was needed; the occupations where successful men were venerated for their brains. It was reserved for the nineteenth century to recognize the dominance of abstract thought in a new field—the field of constructive effort—and to revere the trained scientific expert for what he had done in these lines. Engineering which a hundred years ago was but a subordinate branch of the military art, has become in the years which have since elapsed a dominant factor in the intelligent practice of every art where power is to be applied with economy and intelligence.

A building like this is therefore the symbol of all that is most distinctive in the thought of the century that has gone by. A hundred years ago we might have had a building in honor of theologians or of lawyers or of physicians; but one that symbolized the achievements of the engineer was beyond man's dreams, because the world at large had neither felt the need of his work nor dreamed how soon it would be seeking his leadership.

I have spoken of this building as a monument; but that is after all not the proper word. A monument implies that a man is dead, or at any rate that he has so nearly reached the limit of his growth that he might just as well be dead. Looked at in this way, the engineering profession wants no monument. It has not yet reached the limit of its growth. It has not come to the time when a complacent survey of the past will take the place of toilsome planning for the future. Not a headstone do we want, but a milestone—a point at which our measurement of what has been already done serves as an inspiration for the journey yet to be traversed. We may take this opportunity for a brief review of what has been done in engineering and other allied professions; but the engineer who is worthy of his calling will value that review most highly if it is made a means of calling his attention to that which yet remains to be done.

A hundred years ago there was a sharp separation between scientific theory and commercial practice. There was not a great deal of science anyway, outside of mathematics and astronomy; and what there was was underrated by men of affairs. In those days when a man said he was practical it meant that he was not theoretical; that he didn't know science, and didn't want to know it, and didn't want to have any man around that did know it. The men of that day trusted to two guides: inherited prejudice and individual experience. The more enlightened among them used experience to correct prejudice; the rank and file of them used experience to reinforce prejudice; and that was about all the difference. The value of generalizations,

except in religion and in statecraft, and in some few branches of medicine, was not recognized by anybody.

The great element of progress in the nineteenth century has been the recognition on the part of mankind in general of the value of scientific generalizations in every department of human conduct. Our science has become sounder, our understanding of its applications clearer, and the public has recognized that scientific conduct of a business means the substitution of universal experience, learned with difficulty and applied with toil, for the narrower range of individual experience which was at the disposal of the so called practical men of fifty or a hundred years ago. Of this change the engineer is the representative and the leader. He it is that makes physical science in its various lines applicable to the complex problems of construction and development. He it is who has paved the way for the recognition of the technologist and the expert in every line of human industry. He it is who has shown how mathematics, instead of being an abstract discipline, remote from everyday human affairs, may become the means of applying truths for a long time remote and undiscovered to the everyday affairs of the world in which we live. Not the buildings that you have built, gentlemen; not the railroads that you have planned; not the machines that you have invented, represent your greatest achievement. Yours is the proud boast of having in one brief century established science as the arbiter of the material affairs of mankind, and of having enforced her worship upon a world once reluctant but now gloriously admiring.

Well, then, you will ask: Is there anything which remains to be done comparable in importance to this? Yes; there is. An equally large part—perhaps in one sense a much larger part— of your professional duty yet remains to be accomplished. It is not enough to have technical training. It is not enough to know the special sciences on which the practice of a profession is based. A man ought to have clear conceptions of the public service on which his profession is based; a man ought to have clear conceptions of the public service which his profession can render and the public duty which its members owe. Thus, and thus only, can the engineer, the lawyer, the physician, or a member of any other learned profession, rise to the full dignity of his calling.

For there are two quite distinct qualities which must be combined in order to secure the best professional services; two quite distinct tests which work must meet in order to be pronounced first class. One of these is the technical standard; the other, for want of better word, may be called the ethical standard. The man who wishes to

build a good railroad must not only lay it out according to the rules of the surveyor's art, with proper curves and grades and bridges which will not fall, but he must also have intelligent regard to the needs of the population, the safety of travel, and the many other factors which determine whether a railroad shall be a work of public use or a source of industrial bickering and financial disaster. This combination of public and private demands is not peculiar to engineering. It can be illustrated in every other profession of importance. It is not enough for the lawyer to give advice which shall be technically sound and which shall enable his clients to keep out of jail. He must learn to take a large view of the law as a means of public service instead of private gain. It is not enough for the physician to know how to cure specific diseases. He must know how to care for the larger problems of public health, and to use the resources of the community in a way to meet as fully as possible its sanitary needs.

This larger view of professional obligations is not so fully recognized as it should be. We have in the nineteenth century made so much progress in the technical training of doctors and lawyers and engineers that we sometimes forget that there is need of anything more than technical training. We have let the old idea of public leadership, which was prominent in the minds of the great professional men of past centuries, give place to another and narrower ideal which is fully satisfied when a man has made himself a technical expert. Many a man of real eminence in his calling deliberately rejects the wider conception of professional duty which I have here indicated. Perhaps he recognizes the claims of public service; perhaps he does not, but in any event he believes that these claims rest upon him as a man rather than as an engineer or a lawyer. In his professional capacity he says he is hired, not to tell what the law ought to be, but what it is; not to advise how a railroad can do the most public service, but how certain men with certain ideas of their own can best use the differential calculus to get these ideas carried out. This is perhaps the prevalent view of professional ethics today. I believe that it is a wrong view, which must menace not only the influence and standing of the professions themselves, but the general interests of the republic.

In the first place, a man who believes that he is hired to carry out another man's ideas can never claim a position of actual leadership. He remains a paid servant, highly paid, doubtless, because he is possessed of a kind of skill which is very unusual, but nevertheless a servant, bound to carry out the wishes of his master. A group of professional men who regard this as a proper view thereby forfeit the

claim to stand in the first rank socially and politically, and voluntarily accept a position of the second rank. I do not believe that the engineers of America want to do this. It has been said that engineering is the handmaiden of commerce; but I do not believe that the men who have planned and dedicated this building will be satisfied with any handmaidenly conceptions of what their successors ought to be. If for a moment, in our zeal for new technical developments, we have let our responsibilities as public servants fall out of our hands, I feel sure that we shall be ready to take them up again as soon as our eyes are opened to the real situation.

Mere technical achievement is not the thing that endures. Among the peoples of the ancient world, I suppose that there were no engineers equal to those of Egypt. Considering the means at their command, the things that they did were absolutely extraordinary. They did some things which, even with the means at our command, we can hardly duplicate. But they used their abilities in the service of a dominant priestly caste; and therefore, while their work fills us with admiration, it does not appeal to us as does the work of the Roman engineers a few centuries later, who built roads and aqueducts and bridges, and thus took the lead side by side with the Roman lawyers in establishing the basis of modern civilization. The roads and bridges of Rome, simple and straightforward as they are, constitute a more enduring monument to the Roman engineers than all the obelisks and pyramids that were ever erected.

For their own sake, then, and for the sake of the enduring quality of their work, we can appeal to the engineers and lawyers and physicians to see that it is adapted to public ends. We can reinforce this appeal by a yet stronger one on behalf of the American Commonwealth as a whole. For the development of technical ideals and standards in our various professions during the last few centuries, to the neglect or exclusion of ethical ones, is constituting a very serious public danger.

A commonwealth like that of the United States is necessarily governed by public opinion. Courts may formulate this opinion. Legislatures may pass rules to give effect to it. Police may enforce its demands against the recalcitrant, but the governing power rests in the intelligent public opinion itself. When that opinion ceases to be intelligent and powerful, freedom becomes a mere name. Now, a serviceable public opinion of this kind can only be formed when intelligent people, technically trained for different lines in life, seriously try to find out how their work can be made to meet the public needs. They are the only ones who can do this well. If it is done

by anybody else it will be done badly. If the lawyers as a class try to keep the law in line with the demands of intelligent public opinion, we can get good law. But if lawyers are content to see the law perverted to private ends, and judges take refuge in technical construction of precedents, without full regard to the needs of the existing situation, legislatures will step in to create a chaos of conflicting laws which are worse than no law at all. In like manner, if our engineers get their own minds clear, and get the public mind clear as to the political economy of the properties entrusted to their charge and the ethics of their management, they can forestall these conflicts which now threaten to break out at every moment. But if the members of a profession whose advice is necessary in order to a clear understanding and wise settlement of these problems retire from the field of action, the matter will be settled by those whose interests are more selfish and less far-sighted.

There are three professions today which do not regard themselves as servants, but as masters—the financier, the journalist, and the politician. If the engineer and the lawyer accept position as servants, simply putting their technical knowledge at the disposal of merchant, journalist, or politician who will pay the highest price for it, it is not simply a confession of inferiority—it is a dereliction of public duty.

Do you say that it is impossible for a single man or a group of men to remedy these evils? Look at the career of Albert Finck, who in 1874, when he was an engineer on the Louisville and Nashville Railroad, made a study of the cost of transportation which has been at the basis of all intelligent management of the traffic departments of railroads from that time to this.

Of course, Albert Finck was a rare man. He could do things that some of the rest of us cannot. But, I verily believe, that if our professions could awake to the necessity of broad ideals like those of Finck, the greatest dangers which threaten the American commonwealth would be fairly met, and the men who met them would be given the position of power and trust which they had proved themselves worthy to hold. Nobody is satisfied today with the struggle between individualities and socialism, between financier and politician, between Wall Street and Washington. The men who are engaged in this conflict are for the most part heartily sick of it. Let a man or group of men arise who add to their technical knowledge a readiness to use that knowledge in the public service, and people will be ready to put them in charge of affairs and follow where they lead. We have outgrown the day when a little common sense was sufficient for managing the affairs of the nation. They are become too com-

plex; and this complexity gives the engineer, if he will add to his training in mathematics a training in ethics and political economy and the fundamental principles of the law, an opportunity such as never before existed to claim and receive the position which rightfully belongs to him.

There arises now and then among our engineers a man with this quality of looking into the future— call it genius, call it insight, call it imagination. One of your own members said in a memorable speech that the thing which distinguishes a man of the first rank in his profession from a man of the second rank is the possession of this quality of imagination. Unfortunately it is rare. We cannot all of us have it. But we can have more of it than we now have, if we will modify our training and widen our standards of professional success. Excellent as is the course in our technical schools, it does tend to have a narrowing effect instead of a broadening one. The ideals of our engineering societies are high, but they are not always as broad as they might be. The widening of the course in the schools and greater readiness in our associations to recognize services which we now call non-professional, will, I am convinced, do more for the engineers and more for the community than would be represented by ten years' progress in mining or machinery and the various developments of applied science.

We celebrate today, and we are justified in celebrating, the recognition of science as a necessary guide in the conduct of the material affairs of each man's business. Half a century hence, when our descendants shall meet in this building or some yet greater building, I am confident that they will celebrate a yet greater thing—the recognition of the right of men of science to take the lead in enlightening the thought of the people on public affairs and the responsibility of filling the highest positions in the service of the commonwealth.

Chairman Hunt The dedicatory ceremonies appointed for the day having been completed, I declare that this building is duly dedicated to the advancemennt of the Engineering Arts and Sciences in all their branches.

This meeting is now adjourned.

THE UNVEILING OF THE CARNEGIE BUST

At the close of the Dedication Exercises in the Auditorium, Mr. E. E. Olcott, President of the United Engineering Societies and a small party of ladies and gentlemen escorted Mr. and Mrs. Carnegie to the

Library on the thirteenth floor where a bronze bust of the donor of the building was unveiled by the withdrawal of a flag by Mrs. Carnegie. The beautiful room was decorated for the occasion with bunting and growing plants and the afternoon light shining on its orderly rows of books made an impressive setting for the short ceremony.

The bust stands upon a central pedestal with an ornamental rail which extends across the east end of the Library, and is the work of Mrs. E. Cadwalader Guild. It was presented by the Past Presidents of the Founder Societies and will be to them, we trust, an infinite gratification as a suitable and permanent recognition of the gift the Societies have received from Mr. Carnegie.

INSTITUTIONS OF LEARNING AND ENGINEERING SOCIETIES REPRESENTED AT THE DEDICATION

REPRESENTATIVES OF INSTITUTIONS OF LEARNING

Brown University, Professor William H. Kenerson
Case School of Applied Science, President Charles S. Howe
Thomas S. Clarkson Memorial School of Technology, Director C. Aldrich
University of Cincinnati, President Charles W. Dabney and Dr. Thomas Evans
Colorado College, President William F. Slocum
Colorado School of Mines, Arthur R. Townsend
Columbia University, Frederick A. Goetze, M. Sc. and Professor William H. Burr
Cornell University, Walter C. Kerr
University of Georgia, Professor C. M. Strahan
Haverford College, Professor L. H. Rittenhouse
Johns Hopkins University, R. Brent Keyser
University of Illinois, E. W. Goldschmidt
State College of Kentucky, President James K. Patterson
Lafayette College, President E. D. Warfield
Lehigh University, President Henry S. Drinker
Massachusetts Institute of Technology, Professor R. H. Richards
Michigan Agricultural College, Joseph T. Freeman
University of Michigan, Alfred Noble, alternate, Prof. N. C. Brooks
United States Military Academy, Major Richmond P. Davis
University of Minnesota, Professor Fred S. Jones
University of Missouri, Charles Lewis Harrison
United States Naval Academy, Commander John K. Barton
College of the City of New York, Professor Alfred G. Compton
New York University, Professor Collins P. Bliss and Professor Charles H. Snow
Ohio University, President Alston Ellis
University of Pennsylvania, Professor Henry Wilson Spangler
Western University of Pennsylvania, Chancellor S. B. McCormick
Pennsylvania State College
Polytechnic Institute of Brooklyn, President Fred. W. Atkinson
Pratt Institute, Director Arthur L. Willston
Rensselaer Polytechnic Institute, President P. Ricketts

Rutgers College, Professor Alfred A. Titsworth
Stevens Institute of Technology, Prof. Jas. E. Denton and Dr. D. S. Jacobus
St. John's College, President Thomas Fell
Trinity College, Professor Henry Augustus Perkins
Tufts College, Professor Gardner C. Anthony
Union University, Professor Olin H. Landreth
University of Vermont, Professor W. H. Freedman
Washington and Lee University, President George H. Denny
George Washington University, President Charles Willis Needham
University of Washington, Professor H. K. Benson
Worcester Polytechnic Institute, Professor L. P. Kinnicutt
Yale University, President Arthur T. Hadley

REPRESENTATIVES OF ENGINEERING AND SCIENTIFIC SOCIETIES

American Chemical Society, Marston T. Bogert, President
American Electrochemical Society, Dr. E. F. Roeber
American Foundrymen's Association, Dr. Richard Moldenke, Secretary
American Gas Institute, Henry L. Doherty
American Institute of Architects, Cass Gilbert
American Railway Associations, W. F. Allen, Secretary and Treasurer
American Railway Master Mechanics Association, Arthur M. Waitt, Past-President
American Society of Civil Engineers, Nelson P. Lewis
American Society of Heating and Ventilating Engineers, W. M. Mackay, Secretary
American Society of Municipal Improvements, George W. Tillson, Secretary
American Society of Naval Engineers, Commander Albert Moritz
American Society for Testing Materials, Professor Edgar Marburg, Secretary Treasurer
American Water Works Association, Morris R. Sherrerd
Association of Railway Superintendents of Bridges and Buildings, Joseph H. Cummin
Associazione Elettrotecnica Italiana, J. W. Lieb, Jr.
American Society of Refrigerating Engineers, John E. Storr, Past-President
Boston Society of Civil Engineers, Francis W. Dean, Vice-President
Brooklyn Engineers Club, C. E. Pollock, President
Canadian Society of Civil Engineers, W. McLea Walbank
Concrete Association of New York, Albert Mayer
Corpo Reale Dellé Miniere, Dr. R. W. Raymond
Deutsche Chemische Gesellschaft, Dr. C. F. Chandler
Electrical Contractors Association, James Hilton
Empire State Gas and Electric Association, T. R. Beal, Treasurer
Engineers Club, T. C. Martin, President
Engineers Club of New York, Thos. C. McBride, Past President
Engineers Society of Western New York, Harry B. Alvorson
Faraday Society, Leon Gaster
Geological Society of America, Prof. J. J. Stevenson
Illuminating Engineering Society, Dr. Clayton H. Sharp, President
Institution of Electrical Engineers, Sir William Preece
Iron and Steel Institution, R. A. Hadfield, Past President

KONINKLIJK INSTITUUT VAN INGENIEURS, F. W. Ruhle von Lilienstern ter Meulen
MASTER CAR BUILDERS' ASSOCIATION, F. W. Brazier
MUNICIPAL ENGINEERS OF NEW YORK, George S. Rice, President
NATIONAL ASSOCIATION OF COTTON MANUFACTURERS, Frederick A. Flather
NATIONAL ELECTRIC LIGHT ASSOCIATION, Arthur Williams, President
NATIONAL FIRE PROTECTION ASSOCIATION, Charles A. Hexamer, President
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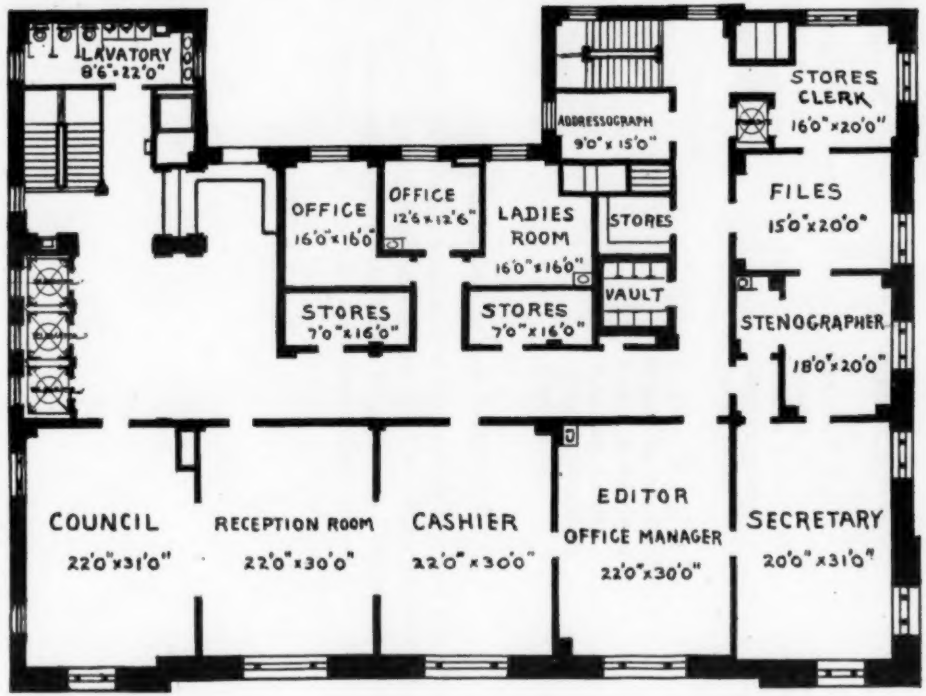
THE SECOND DAY OF DEDICATION

The exercises of the second day of Dedication and also the address of Brigadier General William Crozier, Chief of Ordnance, U. S. A., on "The Ordnance Department as an Engineering Organization," will be published in the June issue of Proceedings.


LAVATORY
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LADIES
ROOM
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VAULT
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CLERK
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STENOGRAPHER
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22'0"×30'0"
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ANNOUNCEMENTS

THE SOCIETY'S HEADQUARTERS

In this issue we are pleased to give the plan of the headquarters of the Society on the eleventh floor of the Engineering Societies building, 29 West 39th Street, New York.

The enlarged space is necessary for the growth of the Society and for the many activities being conducted. We will describe them in the order in which they are seen by one entering.

The reception room to the right of the elevator is conveniently provided with tables and chairs for the comfort of members and others coming to use the Society rooms either as a place of consultation or for writing. Correspondence tables are provided near the window for the use of all. One of the office staff is in attendance at all times to receive visitors and attend to their wants. If necessary to see any of the members of the office, this room affords such opportunity.

To the west, leading out of the reception room, is the Board and Committee room. This in common with all the rooms of the Society has been provided with oak furniture of dark brown finish, in keeping with the trim of the building.

East of the reception room is the accounting room; and next is that of the manager of the office and the editor and the last to the east, that of the Secretary.

The principal innovation and one of the facilities offered to members is the out-of-town members' room, which is the office at the end of the short corridor to the north. This room is fitted with a desk, table, chairs, etc., uniformly with the offices of the Society and is to serve as a regular business office for members coming from a distance, where they may arrange appointments, receive mail, and conduct business. The equipment of the office of the Society, *i. e.*, messenger service, telephone, stenography is to a limited extent available. For any special service required a charge will be made which the member of course, will be pleased to meet.

To accommodate those members desiring to stay in town over night, the Engineers' Club is available and the Secretary will always be pleased to give cards to the Club. In this way the Society is relieved

of the necessity of maintaining a clubhouse as formerly and offers in its stead much more commodious facilities in the clubhouse in connection with the Engineering Societies.

ANDREW CARNEGIE, HONORARY MEMBER

At a meeting of the Council of the Society April 16, 1907, the following nomination for Honorary Member was presented.

To the Council of the American Society of Mechanical Engineers

The undersigned members of the Society hereby propose Andrew Carnegie as a candidate for Honorary Membership in The American Society of Mechanical Engineers. In compliance with paragraph C 13 of the Constitution, we present the following grounds for the nomination:

Andrew Carnegie is the greatest ironmaster the world has ever known.

[Signed]
E. B. Archer
John A. Brashear
John Fritz
John E. Sweet
Thomas Fitch Rowland
S. T. Wellman
Charles Wallace Hunt
Chas. H. Haswell
Thomas A. Edison
Charles H. Morgan
Worcester R. Warner

As required by the constitution election to honorary membership must be without a dissenting vote, and the Secretary is pleased to record that the Council was unanimous in conferring the greatest honor in the power of the Society upon Mr. Carnegie.

SALE OF ELECTROPLATES OF TRANSACTIONS

Owing to the large accumulation of electrotype plates from which the Transactions have been printed and the increasing expense of storage, the Council has decided to sell the plates for Volume 5 to 26 inclusive.

Authors of papers and members who may be interested in any special papers, may have the privilege of buying the plates for those papers on application to the Secretary before June first.

AMENDMENTS TO THE CONSTITUTION

The following amendments to C 38 and C 45 of the Constitution were presented to the Membership as provided for by Section 57, voted upon, and passed by the ballot closing March 4.

AMENDMENT NO. 1

To add to the end of Section C 38 the following:

The Council may also in its discretion appoint a person of the grade of Member to be an Honorary Secretary of the Society for a term not to exceed one year, but he may be reappointed from year to year. He shall perform such duties as may be assigned to him by the Council which are in conformity with the Constitution and By-Laws, and with or without compensation as the Council may direct.

AMENDMENT NO. 2

To add to Article C 45 after the words:

"House Committee" the words "Researce Committee."

The membership is hereby notified of these amendments.

PRESENTATION OF MEDALS FOR DISTINGUISHED SERVICES

A handsome gold medal was presented to Dr. Frederick Remson Hutton on Founders Day of Dedication week in token of appreciation of his twenty-four years of service to the Society as its Secretary.

It bears the following inscription which expresses not only sentiments of the Council, but of the entire membership.

Presented by
the Council of
THE AMERICAN SOCIETY
OF
MECHANICAL ENGINEERS
to
FREDERICK REMSON HUTTON,
E.M., Ph.D., Sc.D.

In grateful appreciation of wise counsel; untiring industry and loyal devotion as Secretary for twenty-four years.

1883–1907

A similar medal was presented to Dr. R. W. Raymond, Secretary of the American Institute of Mining Engineers and to Mr. Ralph W. Pope, Secretary of the American Institute of Electrical Engineers, both of whom, it is remarkable to note, have served a similar length of time.

BALLOT FOR MEMBERSHIP

The ballot for membership closed on March 30 with the election of 42 candidates as Members, 13 for the Associate grade and 34 for the Junior grade.

There were also 14 candidates for promotion to full membership and two for the grade of Associate, making the full number voted upon 105.

The professional records of all Candidates were published in the March issue of Proceedings.

OBITUARY

NORMAN C. STILES

Norman C. Stiles was born in Feeding Hills, Mass., June 18, 1834. He received a common school education, and at an early age took up design and construction at the American Machine Works, Springfield, Mass. He invented and developed many machines for stamping and drawing sheet metals, secured patents on the punching press, drop hammers, and similar machines, and continued their manufacture until 1884. He designed and patented most of the machines now manufactured by the Styles & Parker Press Co., of Middletown, Conn., of which company he has been the principal owner, treasurer, and manager since its formation in 1871.

Mr. Stiles became a member of the Society in 1884, and subsequently became a life member. He was elected manager in 1895 and served on the Council until 1898. He died February 4, 1907, at his home in Hartford, Conn.

HERMAN UNZICKER

Herman Unzicker was born June 7, 1846, in Hessen Nassau, Germany. His preliminary education was received in a technical school, and he served an apprenticeship of several years in a machine shop, later attending a technical school in the State of Brunswick, Germany. Upon leaving school he was engaged as draftsman and designer in several machine shops, and had charge of works as mechanical engineer and foreman.

He came to the United States in 1872 and found employment as draftsman in Chicago, Ill. In May, 1888, he became general superintendent and engineer of the shops of Fraser & Chalmers, Chicago, Ill., with which firm he remained 14 years, as designer and constructor of plants and machinery for the mining and reduction of all classes of ores.

In 1890 Mr. Unzicker organized the Chicago Iron Works, which, however, succumbed during the panic of 1893. Since that time he has been contracting and consulting engineer with E. P. Allis & Co.,

Fraser & Chalmers, and the Allis-Chalmers Co. At the time of his death, February 7, 1907, he was consulting engineer with Chalmers & Williams.

WILLIAM DURELL STIVERS

William Durell Stivers was born in Jersey City, N. J., February 20, 1871. He received his education in the public schools, graduated from the high school in 1887, and pursued some special studies in mechanical engineering at the Cooper Institute in New York. He entered the DeLamater Iron Works in 1887 and was assigned to special service in the superintendent's office where he had unusual opportunity for acquiring a special training in shop management, engineering and experimental work. While there he took part in various interesting experiments that were conducted at the DeLamater Iron Works, as, for instance, those of the noted Ericsson expansion engine, the hot air engine, the Belleville boiler, refrigerating and compressed air machinery, and other constructions. After the dissolution of the DeLamater Iron Works in 1889, Mr. Stivers entered the Quintard Iron Works as draughtsman, eventually rising to the position of acting superintendent. He supervised the building and installation of the machinery of the U. S. S. "Maine" which was destroyed in Havana Harbor. He was the works representative on the trial trips of the U. S. S. "Concord," "Bennington," "Detroit" and "Marblehead." He also had a prominent part in the trial trip of the U. S. S. "Bancroft." In 1902 he left the Quintard Iron Works to accept the position of superintendent of the Yonkers Works of the Otis Elevator Company, which position he held until March, 1904, when he was engaged by the C. W. Hunt Co. as executive engineer, remaining active in that place until his death in December, 1906. He joined the Society in 1904.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both as to positions and as to men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 20th of the month. The list of men available is made up entirely of members of the Society and these are on file, with the names of other good men, not members of the Society, capable of filling responsible positions, information about whom will be sent upon application.

POSITIONS AVAILABLE

038 Manager wanted for large factory located in England. Must have successful practical experience in the manufacture of small tools, including high speed twist drills of the highest grade. Must have thorough technical and general education, some commercial and executive experience. Permanent position and good salary. Apply by letter, stating age and experience.

039 Machine shop foreman wanted by public service corporation in large city on Great Lakes. Salary, $1500. Prefer young man with varied experience, familiar with modern machine tools. Work includes repairs to electric motors, gasolene automobiles, arc lamps, construction tools; also construction of special apparatus and certain amount of small manufacture.

040 Business confined practically to designing and erecting in reinforced concrete of factory, warehouse, or similar buildings. Extensive experience with this material not an essential qualification, good judgment, some experience with construction work in general, and the ability to organize the work being more important. Location, New York.

041 Man in a superior capacity in old established factory. Salary around $2000 per annum. Age, 30 to 50. Non-union. Ability to mix well with men without causing friction. Near New York City. Products, cast iron, japanned, baked or plated with bronze copper, etc. Man should be able to make formulas for cast iron melting; have a good knowledge and experience in molding, patterns, japanning, baking and plating.

042 General Manager for factory and foundry; ball bearings for automobiles and other purposes are part of the production. Applicant would need to have some money which he could invest. Salary, to start, $5000. Location, Rhode Island.

043 Instructor wanted by educational institution for rolling mill design and blast furnace construction. Preference given to technical graduate with at least four years' practical experience. Address replies to Secretary of the society. Location, Western Pennsylvania.

044 Mechanical and electrical engineer of about 10 years' experience, capable of taking responsible charge under Superintendent, more especially of the electrical end of plants.

045 Superintendent of works employing 170 to 200 men in the manufacturing departments, with thoroughly practical experience in auto part work and assembly of parts.

046 Young man wanted to fill position in planning department of cotton mills, to have charge of analysis of orders, order of work sheets, and of time study and investigations relating to improved methods. Location, New Jersey.

047 Assistant superintendent for separator works. Location, New York State.

048 Salesman for oils.

MEN AVAILABLE

In addition to the list of men available, the Society is pleased to announce that one of the colleges has volunteered to undertake to supply both undergraduate and graduate students for part time, summer and permanent positions. The Secretary will be pleased to be the medium for correspondence.

67 Technical graduate of 15 years' experience in heavy machine design, ordnance work, general machinery and tools, and production relating to modern shop practice, also as machinery salesman desires position as representative, mechanical engineer, or assistant superintendent.

68 Member of Society, at present employed, with best references, experience, ability, could qualify as business manager, office manager, or engineer salesman. Location, preferably New York or farther South.

69 Mechanical engineer engaged in teaching in a technical college of the first rank, desires a position in practice during the summer vacation of 1907. Good experience in executive work, including the handling of men; in engineering calculation and design; in testing

and experimental work; and in the inspection of machinery and engineers' tools, stores, and supplies. Power plant work a specialty.

70 Junior member, 37 years of age, desires a change. Technical graduate; five years' drafting room experience, designing of automatic machinery, tools, jigs, etc. Three years' shop experience; ten years' teaching experience, principally mechanical engineering subjects and design in a technical school of high rank. Will consider position in either teaching or commercial line.

71 Member with 20 years' railroad experience as foreman, draftsman, and master mechanic desires a position, preferably in California.

72 Chief engineer with many years' experience in superintending construction, letting contracts, making estimates, etc., and operating power plants.

73 Mechanical engineer with varied experience in foundry and machine shop as engineer and superintendent, desires connection with foundry and machine shop in northern Ohio. Can command considerable trade.

74 Mechanical engineer, technical graduate and practical mechanic, with office in Cleveland, desires to act as representative or inspector for concern having work done in this vicinity. Has had charge of foundry and machine shop, etc., and understands "pushing work" advantageously.

75 Mechanical engineer, age 39, experienced in building, equipping, and organizing plants. Has been particularly successful as sales manager; can handle large deals and get business. Desires to make a change to a position as sales manager or purchasing agent.

76 Member, seven years on machine tools and automatic machinery; three years on power cranes and hoists; seven years on heavy pumping engines and mining machinery; four years as assistant shop engineer in charge of machine tools, buildings, maintenance and equipment; one year as manager improving pneumatic motor hoists; three years as shop engineer in charge of equipment, maintenance, machine tools, etc.

77 Technical education, 20 years' broad experience, thoroughly competent on reinforced concrete, mill design and maintenance, power plants, cement mills and steam turbine installation.

78 Junior member, technical graduate. Six years' experience in marine engineering in drafting, estimating, shop, foundry work and trial trips of ships. Also instructor in mechanical engineering, steam

engineering and laboratory work. Position desired with firm where the work will be general steam engineering.

79 Superintendent or manager, good organizing and executive ability. Expert in machine-shop and manufacturing methods to increase production and reduce costs. Wide experience, is tactful in the management of men. Understands the "Premium Plan" of paying for labor, and the results that can be obtained by its use.

80 Graduate Yale and Cornell, has held position as works manager, chief engineer, and executive engineer in prominent companies in the United States and England, desires position along similar lines, preferably in New York.

81 Young mechanical and electrical engineer, university graduate having shop, drafting room and office experience, desires change.

82 Mechanical engineer at present vice-president and general manager of company manufacturing machinery, having charge of manufacturing, designing and financial departments. Experience with steel companies as designer and in selling. Qualified for executive position.

83 Member, 39 years old, graduate of Cornell University, thoroughly familiar with up-to-date shop practice, cost and record systems; desires position as superintendent or works manager.

84 Member of long experience with steam turbines and Corliss engines, as engineer in chief, in designing, erecting and maintaining of plants desires position with large concern where engineering experience and business knowledge would be useful.

ACCESSIONS TO THE LIBRARY

Donations[1]

Locomotives, Simple, Compound, and Electric. By H. C. Reagan, Locomotive Engineer. *Fifth Edition, Revised and Enlarged. John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1907.* Cloth, 8vo, $3.50.

Contents, by chapter headings: The Locomotive Boiler; Front End, or Smoke-arch; Steam cylinders and Connection; Locomotive Frames; Driving boxes and Spring Rigging; Rods and Connections; Breaking of Rods; Valve motion; Valve setting; The Compound Locomotive; Indicator cards; Description of Various Systems of Compound Locomotives; Recent American Compound Locomotives; Foreign built Compound Locomotives; Superheaters as Applied to Locomotives; The Reading's Single driver Locomotive for the Royal Blue Trains; The 1895 Class "L" Express Engines for the Pennsylvania R. R.; Modern French Locomotive; Intercepting valve for Compound Engines; Injectors, Safety Valves, Steam gages, etc.; Brakes Air pumps, Valves, Pump governors, and Westinghouse Brakes; Locomotive Packings; Track sanding Apparatus; Locomotive Valve Mechanism; Liquid Fuel; Oil burning Locomotives, The Modern Locomotive Boiler and Fire box; Generating Current for the Electric Locomotive; Electric Locomotives; Prime Movers Used for Generating Alternating Current; Apparatu; Essential to the Operation of an Alternating Current Electric Locomotive; Electric Loco-s motives Operating on Alternating Current Systems; Electric Control Systems of Locomotives; New York, New Haven and Hartford Electric Locomotive, Westinghouse System. Operating on Direct and Alternating Current; Air brakes for Electric Locomotives and Cars; Gasolene Electric Locomotives; Index.

Problems of the Panama Canal. By Brig. Gen. Henry L. Abbot, U. S. Army, Retired. *The Macmillan Co., New York; Macmillan & Co., Ltd., London.* Cloth, 8vo, $2.

Contents, by chapter headings: The new Panama Canal Company; The Canal Under the Control of the United States; The Rival Routes, Physical Conditions of the Isthmus; The Chagres River; Disposal of Rainfall, Basin above Bohio; Engineer Projects for the Canal; Panama and Nicaragua.

Donations from Members

Steam Turbine Practice and Theory. By Lester G. French. *The Technical Press, Brattleboro, Vt., 1907.* Cloth, 8vo, $2.

Contents, by chapter headings: Steam Turbine Principles; Early Steam Turbine Patents; Simple Impulse Turbines; The Pelton and Similar Types; Compound impulse Turbines—Multicellar Type. Compound Impulse Turbines (continued); Reaction Turbines; Miscellaneou; Turbines and Apparatus; Steam Turbine Performance; Comparison with the Steam Engines Experiments on the Flow of Steam; Steam and its Properties; Calculations on the Flow of Steam Turbine Vanes; Bodies Rotating at High Speed; Notes on Efficiency and Design. The Commercial Aspect of the Turbine. Care and Management. Condensing Apparatus for High Vacuum. The Status of the Marine Turbine.

Weights and Measures Reform, British-American Views. *Pamphlet.*

[1]Books in this list have been donated by the publishers.

HILFSBUCH FÜR DAMPFMASCHINEN-TECHNIKER. Von Josef Hrabak. Part 1, Practischer Theil. Part 2, Theoretischer Theil. *Berlin, 1907.*

INTERNATIONAL CORRESPONDENCE SCHOOLS, SCRANTON, PA. Fifteenth Anniversary Exercises and Banquet. *October, 1891–1906.*

EXCHANGES AND PURCHASES

NOVA SCOTIA INSTITUTE OF SCIENCE. *Proceedings and Transactions. Volume 11, Part 2. 1903, 1904.*

ROYAL SOCIETY OF NEW SOUTH WALES. *Journal and Proceedings, 1905.*

ENGINEERING STANDARDS COMMITTEE. Second Report of the Committee on Standard Locomotives for Indian Railways. *London, February, 1907.*

INTERSTATE COMMERCE COMMISSION. Twentieth Annual Report. *1906.*

ASSOCIATIONS OF ENGINEERING SOCIETIES. *Journal. Volume 38, Number 3. March, 1907.*

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS. *Transactions. Volume 14. 1906.*

THE MECHANICAL HANDLING OF MATERIAL. By George Frederick Zimmer. *New York, 1905.*

MECHANICAL ENGINEERS' POCKETBOOK. By William Kent, *New York. 1906.*

CIVIL ENGINEERS' POCKETBOOK. By John C. Trautwine, *Philadelphia. 1906.*

NAVAL ARCHITECTURE. By Cecil Peabody. *New York, 1904.*

STANDARD PROPORTIONS FOR MACHINE SCREWS

Revised Report of the Committee on Standard Proportions for Machine Screws

To The American Society of Mechanical Engineers:

Having considered the suggestions which have been made since the original report was presented at the New York Meeting, in December, 1905, your Committee now has the honor to present the following amended report.

2 It has been found advisable to change, except in three instances, the nominal outside diameters for the standard sizes of machine screws, and to include in this new list certain additional sizes. The change in the sizes originally proposed varies only from 0.001 inch to 0.003 inch, and avoids an impracticable degree of departure from the already established screw gage diameters.

3 The Standard Diameters for Machine Screws shall be the 21 sizes given in Table 1.

4 The included angle of the thread shall be 60 degrees, with flat at top and bottom of the thread for the basic standard of one-eighth of the pitch, as originally recommended.

5 The uniform increment between all sizes from 0.060 inch to 0.190 inch is 0.013 inch, and between 0.190 inch and including 0.450 inch is 0.026 inch. This conforms approximately to the list of screw gage sizes originally established, in which the increment in 0.01316 inch.

6 This evidently avoids impracticable final decimals, and forms a series in which the sizes have a definite relation to each other.

7 Your Committee has also thought it advisable to make this change, not only in the interest of simplicity and the use of fewer significant figures, but also because the resulting pitch diameters are more nearly in accord with the pitch diameters of machine screws in present use.

Presented at the New York Meeting (December, 1905), at the Chattanooga Meeting (May, 1906), and at the New York Meeting (December, 1906). The Report as now revised to be presented at the Indianapolis Meeting (May, 1907) of The American Society of Mechanical Engineers and to form part of Volume 28 of the Transactions.

TABLE 1 STANDARD MACHINE SCREWS

Basic and Maximum Screw Diameters			Minimum Screw Diameters		
External diam. and No. thds. per in.	Pitch diameter	Root diameter	External diameter	Pitch diameter	Root diameter
.060—80	.0519	.0438	.0572	.0505	.0411
.073—72	.064	.0550	.070	.0625	.052
.086—64	.0759	.0657	.0828	.0743	.0624
.099—56	.0874	.0758	.0955	.0857	.0721
.112—48	.0985	.0839	.1082	.0966	.0808
.125—44	.1102	.0955	.1210	.1082	.0910
.138—40	.1218	.1055	.1338	.1197	.1007
.151—36	.1330	.1149	.1466	.1308	.1097
.164—36	.146	.1279	.1596	.1438	.1227
.177—32	.1567	.1364	.1723	.1544	.1307
.190—30	.1684	.1467	.1852	.166	.1407
.216—28	.1928	.1696	.2111	.1903	.1633
.242—24	.2149	.1879	.2368	.2123	.1807
.268—22	.2385	.209	.2626	.2358	.2013
.294—20	.2615	.229	.2884	.2587	.2208
.320—20	.2875	.255	.3144	.2847	.2468
.346—18	.3099	.2738	.3402	.3070	.2649
.372—16	.3314	.2908	.366	.3284	.281
.398—16	.3574	.3168	.392	.3544	.307
.424—14	.3776	.3312	.4178	.3745	.3204
.450—14	.4036	.3572	.4438	.4005	.3464

8 The pitches are a function of the diameter, as expressed by the formula, threads per inch =

$$\frac{6.5}{D + 0.02}$$

and the results are given approximately and in even numbers in order to avoid the use of fractional or odd number threads.

9 In recommending certain limits for variation from the basic standard, the maximum screw shall conform practically in all respects to the basic standards. The minimum screw shall have a flat at bottom of the thread of one-sixteenth of the pitch and the difference between the maximum and the minimum root diameter will allow at bottom of the thread any width of flat between one-sixteenth and one-eighth of the pitch, thus providing allowance for variation. See diagram, Fig. 1.

10 The maximum tap shall have a flat at top of the thread equal to one-sixteenth of the pitch and the difference between maximum and minimum external diameter will allow at the top of thread of tap any width of flat between one-sixteenth and one-eighth of the pitch.

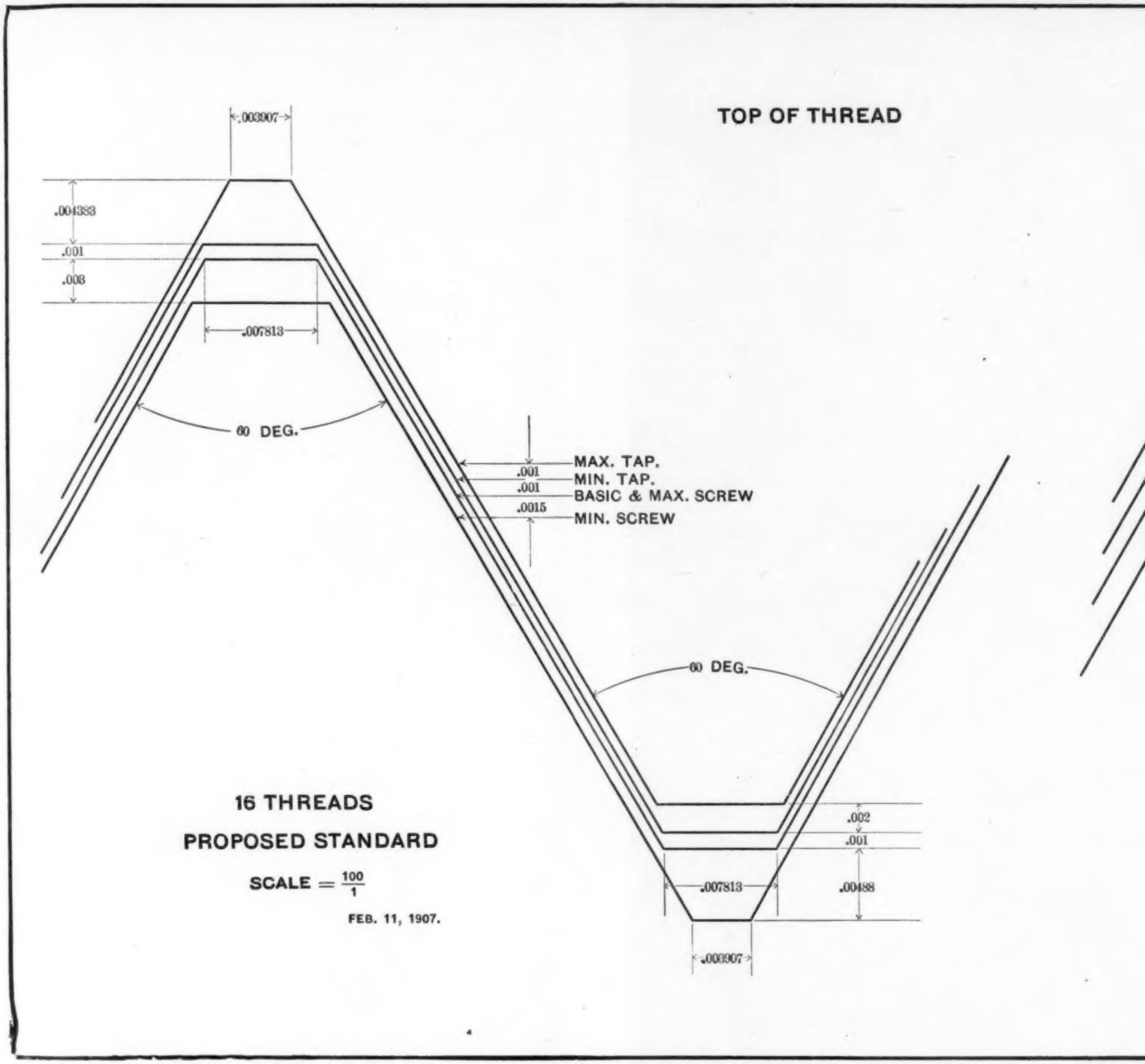
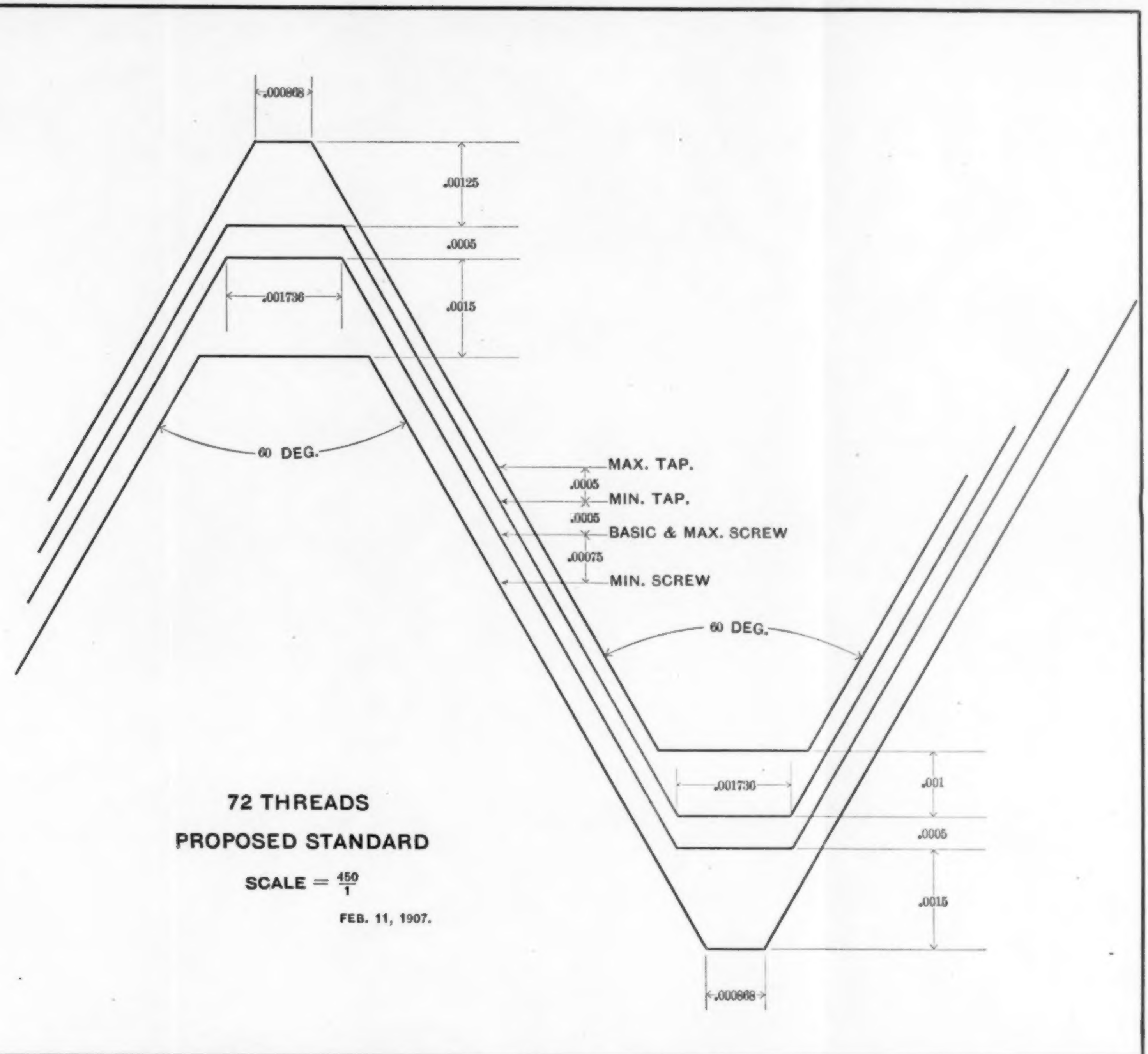


FIG. 1. DIAGRAM SHOWING FORM OF BASIC MAXIMU



IC MAXIMUM AND MINIMUM SCREW AND TAP THREADS

11 The minimum tap shall conform to the basic standard in all respects except diameter, as clearly shown by the diagram Fig. 1.

12 The difference between the minimum tap and the maximum screw provides an allowance for error in pitch, or lead, and for the wear of tap in service.

13 The form of tap thread shown in the diagram is recommended as being stronger and more serviceable than the so-called V thread, but it has been suggested that strict adherence to the form shown might, in the case of small taps, add to their cost.

14 Your Committee would say, however, that taps with V threads and with the correct angle and pitch diameters used in connection with tap drills of correct diameter, are permissible. This will also utilize a large proportion of the V thread taps now in stock.

TABLE 2

FORMULAE FOR PROPOSED STANDARD FOR MACHINE SCREWS AND TAPS. BASIC STANDARD THREAD, U. S. FORM

SCREWS

Max. External Diam. = Basic External Diam.
Max. Pitch Diam. = Basic Pitch Diam.
Max. Root Diam. = Basic Root Diam.

$$\text{Min. External Diam.} = \text{Basic External Diam.} - \frac{.336}{\text{T.P.I.}+40}$$

$$\text{Min. Pitch Diam.} = \text{Basic Pitch Diam.} - \frac{.168}{\text{T.P.I.}+40}$$

$$\text{Min. Root Diam.} = \text{Basic Root Diam.} - \left[\frac{.10825}{\text{T.P.I.}} + \frac{.168}{\text{T.P.I.}+40}\right]$$

TAPS

$$\text{Max. External Diam.} = \text{Basic External Diam.} + \frac{.10825}{\text{T.P.I.}} + \frac{.224}{\text{T.P.I.}+40}$$

$$\text{Max. Pitch Diam.} = \text{Basic Pitch Diam.} + \frac{.224}{\text{T.P.I.}+40}$$

$$\text{Max. Root Diam.} = \text{Basic Root Diam.} + \frac{.336}{\text{T.P.I.}+40}$$

$$\text{Min. External Diam.} = \text{Basic External Diam.} + \frac{.112}{\text{T.P.I.}+40}$$

$$\text{Min. Pitch Diam.} = \text{Basic Pitch Diam.} + \frac{.112}{\text{T.P.I.}+40}$$

$$\text{Min. Root Diam.} = \text{Basic Root Diam} + \frac{.112}{\text{T.P.I.}+40}$$

Note—T. P. I. = Threads per Inch.

TABLE 3

PROPOSED STANDARD OF MACHINE SCREWS

DIFFERENCES BETWEEN MAXIMUM AND MINIMUM DIAMETERS

Threads per inch	External	Pitch	Root
80	.0028	.0014	.0028
72	.003	.0015	.0030
64	.0032	.0016	.0033
56	.0035	.0017	.0037
48	.0038	.0019	.0042
44	.0040	.0020	.0045
40	.0042	.0021	.0048
36	.0044	.0022	.0052
32	.0047	.0023	.0057
30	.0048	.0024	.0060
28	.0049	.0024	.0063
24	.0052	.0026	.0071
22	.0054	.0027	.0076
20	.0056	.0028	.0082
18	.0058	.0029	.0089
16	.0060	.003	.0098
14	.0062	.0031	.0108
Formulae	$\frac{.336}{\text{T. P. I.}+40}$	$\frac{.168}{\text{T. P. I.}+40}$	$\frac{.10825}{\text{T.P.I.}} + \frac{.168}{\text{T.P.I.}+40}$
Note—T. P. I. = Threads per inch.			

STANDARD REFERENCE THREAD GAGES

15 Your Committee again recommends the use of standard reference thread gages for establishing the basic outside and pitch diameters, with flat at top and bottom of the thread of one-eighth of the pitch, to represent exactly in every detail, the data required for maintaining the standard machine screw sizes here submitted.

16 The reference thread gages include also reference thread gages for screws and reference thread gages for taps, each of these represent the limiting diameters and details for the maximum and minimum allowance, as compared with the basic standard reference thread gages.

17 These gages are represented by Figs. 2, 3, and 4, respectively, and are to be made of unhardened steel, of 0.35 per cent carbon, plug gages only, as originally recommended by your Committee in 1905.

LIMITS OF VARIATION IN SCREW AND TAP DIAMETERS

18 In carrying out the principle of simplification, your Committee presents herewith revised formulae for determining the limits of variation found practical for screw and tap diameters. These

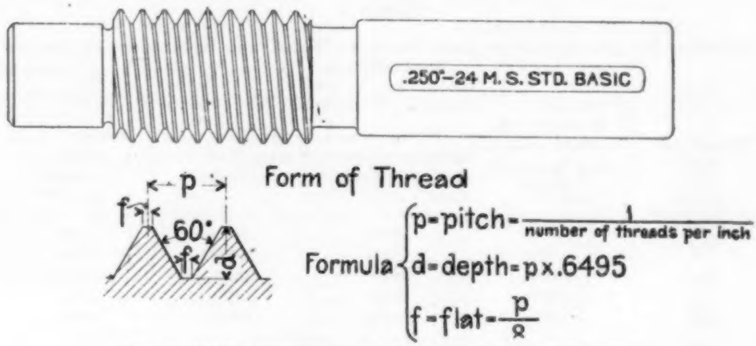


FIG. 2 BASIC STANDARD REFERENCE THREAD GAGE

TABLE 4 TAPS

Size and No. thds. per inch	Minimum			Maximum		
	External diameter	Pitch diameter	Root diameter	External diameter	Pitch diameter	Root diameter
.060—80	.0609	.0528	.0447	.0632	.0538	.0466
.073—72	.074	.065	.056	.0766	.066	.058
.086—64	.0871	.0769	.0668	.0898	.078	.0689
.099—56	.1002	.0886	.077	.1033	.0897	.0793
.112—48	.1133	.0997	.086	.1168	.101	.0877
.125—44	.1263	.1116	.097	.1301	.1129	.0995
.138—40	.1394	.1232	.1069	.1435	.1296	.1097
.151—36	.1525	.1345	.1164	.1539	.1359	.1193
.164—36	.1655	.1474	.1294	.170	.1489	.1323
.177—32	.1786	.1583	.138	.1835	.1598	.1411
.190—30	.1916	.170	.1483	.1968	.1716	.1515
.216—28	.2176	.1944	.1712	.2232	.1961	.1745
.242—24	.2438	.2166	.1896	.250	.2184	.1931
.268—22	.2698	.2403	.2108	.2765	.2421	.2144
.294—20	.2959	.2634	.2309	.3031	.2653	.2346
.320—20	.3219	.2894	.2569	.3291	.2913	.2606
.346—18	.3479	.3119	.2758	.3559	.3137	.2796
.372—16	.374	.3334	.2928	.3828	.3364	.2968
.398—16	.400	.3594	.3188	.4088	.3614	.3228
.424—14	.4261	.3797	.3333	.4359	.3818	.3374
.450—14	.4521	.4056	.3593	.4619	.4078	.3634

formulae for screws include maximum and minimum external, root, and pitch diameters, and are given in Table 2.

19 The limits for screws for each pitch are given in Table 3, and are the amounts less than basic standard for minimum screws, the maximum limit being standard.

TABLE 5

EXCESS OF TAP DIAMETER OVER BASIC DIAMETER BASED UPON EACH PITCH OF THREAD RECOMMENDED

Threads per inch	Excess of min. external, pitch and root diam. over basic	Excess of max. external diam. over basic	Excess of max. pitch diam. over basic	Excess of max. root diam. over basic
80	.0009	.0032	.0019	.0028
72	.0010	.0035	.0020	.0030
64	.0011	.0038	.0022	.0032
56	.0012	.0043	.0023	.0035
48	.0013	.0048	.0025	.0038
44	.0013	.0051	.0027	.0040
40	.0014	.0055	.0028	.0042
36	.0015	.0059	.0029	.0044
32	.0016	.0065	.0031	.0047
30	.0016	.0068	.0032	.0048
28	.0016	.0072	.0033	.0049
24	.0018	.0080	.0035	.0053
22	.0018	.0085	.0036	.0054
20	.0019	.0091	.0037	.0056
18	.0019	.0099	.0039	.0058
16	.0020	.0108	.0040	.0060
14	.0021	.0119	.0042	.0062
	Formula = $\frac{.112}{\text{T.P.I.}+40}$	Formula = $\frac{.10825}{\text{T.P.I.}}+\frac{.224}{\text{T.P.I.}+40}$	Formula = $\frac{.224}{\text{T.P.I.}+40}$	Formula = $\frac{.336}{\text{T.P.I.}+40}$

Note—T. P. I.=Threads per inch.

Note—The formulae given are expressed in terms of *threads per inch* instead of pitch, thus avoiding the use of the reciprocal of each, which obviously involves a greater number of decimals.

20 The diameters recommended for limits for taps are also given herewith, and comprise the maximum and minimum external, root, and pitch diameters. See Table 4. Table 5 shows the excess of tap diameter over that of basic standard.

These formulae also provide a limit to allow for variation of pitch as well as for the diameter of screw and taps.

21 Your Committee desires to state again that the screws here considered are those known as pressed head machine screws; are manufactured in great quantities, and are listed and sold to the trade by the gross. These formulae however, apply equally well to the

TABLE 6 SPECIAL SIZES
SCREWS

BASIC AND MAXIMUM SCREW DIAMETERS			MINIMUM SCREW DIAMETERS		
External dia. and no. of thds. per inch	Pitch diameter	Root diameter	External diameter	Pitch diameter	Root diameter
.073—64	.0629	.0527	.0708	.0613	.0494
.086—56	.0744	.0628	.0825	.0727	.0591
.099—48	.0855	.0719	.0952	.0836	.0678
.112—40	.0958	.0795	.1078	.0937	.0747
—36	.0940	.0759	.1076	.0918	.0707
.125—40	.1088	.0925	.1208	.1067	.0877
—36	.1070	.0889	.1206	.1048	.0837
.138—36	.1200	.1019	.1336	.1178	.0967
—32	.1177	.0974	.1333	.1154	.0917
.151—32	.1307	.1104	.1463	.1284	.1047
—30	.1294	.1077	.1462	.1272	.1017
.164—32	.1437	.1234	.1593	.1414	.1177
—30	.1424	.1207	.1592	.1400	.1147
.177—30	.1453	.1337	.1722	.1429	.1277
—24	.1499	.1229	.1718	.1473	.1158
.190—32	.1697	.1494	.1853	.1675	.1437
—24	.1629	.1359	.1848	.1604	.1287
.216—24	.1889	.1619	.2108	.1864	.1547
.242—20	.2095	.1770	.2364	.2067	.1688
.268—20	.2355	.2030	.2624	2327	.1948
.294—18	.2579	.2218	.2882	.2550	.2129
.320—18	.2839	.2478	.3142	.281	.2389
.346—16	.3054	.2648	.340	.3024	.2550
.372—18	.3359	.2998	.3663	.3330	.2909
.398—14	.3516	.3052	.3918	.3485	.2944
.424—16	.3834	.3428	.4180	.3804	.3330
.450—16	.4094	.3688	.4440	.4064	.3590

diameter of corresponding sizes if made by machine operation from stock which is the diameter of the required head. The formulae for heads given in your Committee's report, are for pressed head screws only.

22 In reference to the discussion of the original report of your Committee relative to heads of machine screws having a flat top and upper corners rounded, this has been carefully considered, but your Committee has been unable to find in any published lists of the manufacturers of machine screws of the character covered by this report

any reference to heads of this kind. This form of head has therefore been omitted. The heads considered and shown by this report are those commonly used and listed by all the leading manufacturers of such machine screws.

23 Tables 6 and 7 are here given covering the list of special sizes of screws and taps with the additional pitches for each, which are in

TABLE 7 SPECIAL SIZES

TAPS

Size and no. of thds. per inch	Minimum			Maximum		
	External diameter	Pitch diameter	Root diameter	External diameter	Pitch diameter	Root diameter
.073—64	.0741	.064	.0538	.0768	.0651	.0559
.086—56	.0872	.0756	.064	.0903	.0767	.0663
.099—48	.1003	.0867	.0732	.1038	.088	.0758
.112—40	.1134	.0972	.081	.1175	.0986	.0837
—36	.1135	.0955	.0774	.1179	.0969	.0803
.125—40	.1264	.1102	.094	.1305	.1116	.0967
—36	.1265	.1085	.0904	.1309	.1099	.0933
.138—36	.1395	.1215	.1034	.1439	.1229	.1063
—32	.1396	.1193	.099	.1445	.1208	.1021
.151—32	.1526	.1313	.112	.1575	.1338	.1151
—30	.1526	.131	.1093	.1578	.1326	.1125
.164—32	.1656	.1453	.125	.1705	.1468	.1281
—30	.1656	.144	.1223	.1708	.1454	.1255
.177—30	.1786	.1469	.1353	.1839	.1485	.1385
—24	.1788	.1517	.1247	.185	.1534	.1282
.190—32	.1916	.1713	.151	.1965	.1728	.1541
—24	.1918	.1647	.1376	.198	.1664	.1411
.216—24	.2178	.1907	.1636	.224	.1924	.1671
.242—20	.2439	.2114	.1789	.2511	.2133	.1826
.268—20	.2699	.2374	.2049	.2771	.2393	.2086
.294—18	.2959	.2599	.2238	.3039	.2617	.2277
.320—18	.3219	.2859	.2498	.3299	.2877	.2536
.346—16	.348	.3074	.2668	.3568	.3094	.2708
.372—18	.3739	.3379	.3018	.3819	.3397	.3056
.398—14	.4001	.3537	.3073	.4099	.3558	.3114
.424—16	.426	.3854	.3448	.4348	.3874	.3488
.450—16	.452	.4114	.3708	.4608	.4134	.3748

use for purposes requiring a different number of threads per inch than is given in the list of standards recommended by your Committee. The formulae are alike applicable to these special sizes and pitches for limits, in external, root, and pitch diameters, and are inserted for convenience of reference.

24 Table 8 gives the thickness of double end templet thread gages

TABLE 8

DOUBLE END TEMPLET THREAD GAGES FOR INSPECTION OF SCREWS

Thickness = $\sqrt{\text{Pitch}} \times 1.443$

Threads per inch	Thickness	Threads per inch	Thickness
80	0.161	30	0.263
72	0.170	28	0.273
64	0.180	24	0.295
56	0.193	22	0.308
48	0.208	20	0.323
44	0.217	18	0.345
40	0.228	16	0.361
36	0.240	14	0.385
32	0.255		

for each pitch of the standard screws recommended for the practical inspection of machine screws. The formula,

$$\text{Thickness} = \sqrt{\text{Pitch}} \times 1.443$$

gives the maximum limit for screws, and provides also a limit for the error in lead of screws and taps. It applies as well to other special pitches covered by the list of those given in Tables 6 and 7.

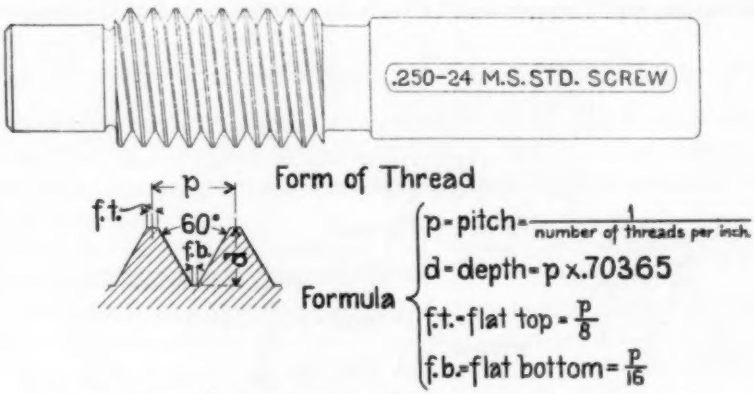


FIG. 3 STANDARD REFERENCE THREAD GAGES FOR SCREWS

25 These templet thread gages to be made of steel, hardened, and double end, with maximum and minimum limits, respectively, and to represent accurately at the plus end, the pitch and root diameters of the basic standard; while at the minus end they should represent the minimum limit for the pitch and root diameters of screws, as given in columns 3 and 4, of Table 3.

26 The threads of these templet gages to be made by taps having the thread enough larger than standard in outside diameter to insure clearance at the top of the thread of the screw.

27 In addition to the threaded or tapped holes, these gages should have plain cylindrical holes representing, respectively, the external diameter of the maximum and minimum screw.

TABLE 9 TAP DRILL DIAMETERS, STANDARD

.060—80	.0465	.216—28	.173
.073—72	.0595	.242—24	.1935
.086—64	.070	.268—22	.213
.099—56	.0785	.294—20	.234
.112—48	.089	.320—20	[illegible]
.125—44	.0995	.346—18	.281
.138—40	.110	.372—16	.295
.151—36	.120	.398—16	.323
.164—36	.136	.424—14	.339
.177—32	.1405	.450—14	.368
.190—30	.152		

28 These templet gages are designed to admit at the maximum end all screws that are within the limits, and to reject all screws that are larger, while screws smaller than the minimum end of the templet

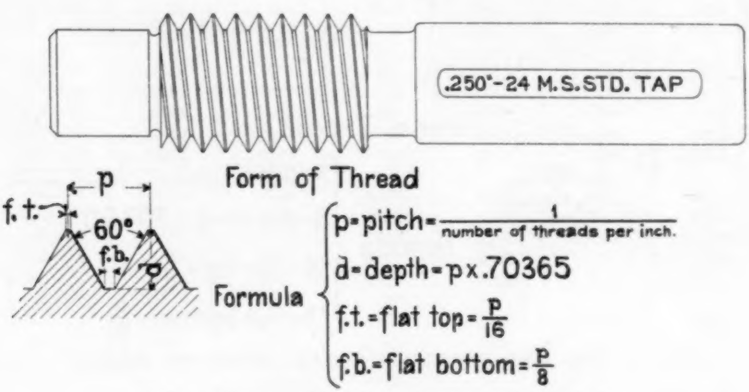


FIG 4 REFERENCE THREAD GAGES FOR TAPS

gage are thus shonw to be less in diameter than is specified by the minimum limit recommended by your Committee.

29 For the convenience of users of machine screws and taps, Table 9 is here inserted, giving the diameter of drills for holes to be

tapped for the standard machine screws covered by this report, and also Table 10, for taps included in the list of special sizes and pitches shown in Table 6. The diameter given for each hole to be tapped allows for a practical clearance at the root of the thread of the screw and will not impose undue strain upon the tap in service.

HEADS FOR STANDARD MACHINE SCREWS

30 Certain changes have been made necessary in the tables for the dimensions of heads for standard machine screws, due to the

TABLE 10 TAP DRILL DIAMETERS, SPECIAL

.073—64	.055	—24	.1285
.086—56	.0670	.190—32	.154
.099—48	.076	—24	.140
.112—40	.082	.216—24	.166
—36	.080	.242—20	.182
.125—40	.098	.268—20	.209
—36	.0935	.294—18	.228
.138—36	.1065	.320—18	.257
—32	.1015	.346—16	.272
.151—32	.116	.372—18	.302
—30	.113	.398—14	.316
.164—32	.1285	.424—16	.348
—30	.1285	.450—16	.377
.177—30	.136		

difference in body diameters, as compared with the list as originally submitted, and are given in Tables 11, 12, 13, and 14. The formulae for the details are given with each table, with the type of each style of head accompanying.

31 The list of heads comprise Flat, Round, Flat Fillister Head, and Oval Fillister Head screws.

32 Flat head screws have an included angle of 82 degrees, which is a maximum angle for this style head, but a reduction of this angle of not more than one or two degrees, due to the wear of tools in their manufacture, may be tolerated.

33 Round heads, so called, are, however, in axial cross section, a semi-ellipse, hence formulae B and C cover all the practical details for determining their form.

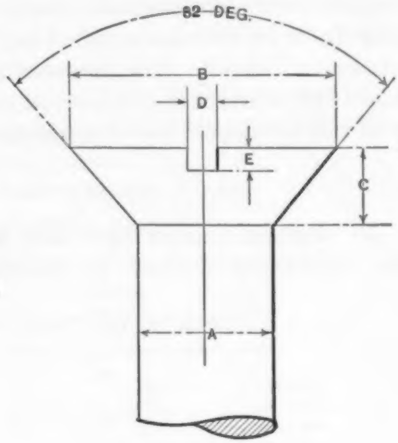


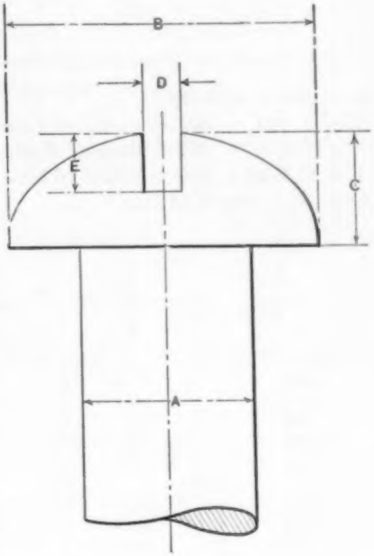
TABLE 11 FLAT HEAD SCREWS

A = Diameter of Body
2A − .008 = Diameter of Head
$C = A - \frac{.008}{1.739}$ = Thickness of Head
D = .173A + .015 = Width of Slot
E = $\frac{1}{3}$C = Depth of Slot

A	B	C	D	E
.060	.112	.029	.025	.010
.073	.138	.037	.028	.012
.086	.164	.045	.030	.015
.099	.190	.052	.032	.017
.112	.216	.060	.034	.020
.125	.242	.067	.037	.022
.138	.262	.075	.039	.025
.151	.294	.082	.041	.027
.164	.320	.090	.043	.030
.177	.346	.097	.046	.032
.190	.372	.105	.048	.035
.216	.424	.120	.052	.040
.242	.472	.135	.057	.045
.268	.528	.150	.061	.050
.294	.580	.164	.066	.055
.320	.632	.179	.070	.060
.346	.682	.194	.075	.065
.372	.732	.209	.079	.070
.398	.788	.224	.084	.075
.424	.840	.239	.088	.080
.450	.892	.254	.093	.085

TABLE 12 ROUND HEAD SCREWS

A = Diam. of Body
B = 1.85A − .005 = Diam. of Head
C = .7A = Height of Head
D = 1.73A + .015 = Width of Slot
E = ½C + .01 = Depth of Slot



A	B	C	D	E
.060	.106	.042	.025	.031
.073	.130	.051	.028	.035
.086	.154	.060	.030	.040
.099	.178	.069	.032	.044
.112	.202	.078	.034	.049
.125	.226	.087	.037	.053
.138	.250	.096	.039	.058
.151	.274	.105	.041	.062
.164	.298	.114	.043	.067
.177	.322	.123	.046	.071
.190	.346	.133	.048	.076
.216	.394	.151	.052	.085
.242	.443	.169	.057	.094
.268	.491	.187	.061	.103
.294	.539	.205	.066	.112
.320	.587	.224	.070	.122
.346	.635	.242	.075	.131
.372	.683	.260	.079	.140
.398	.731	.278	.084	.149
.424	.779	.296	.088	.158
.450	.827	.315	.093	.167

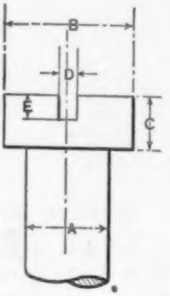


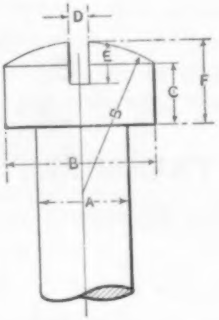
TABLE 13 FLAT FILLISTER HEAD SCREWS

A = Diam. of Body
B = 1.64A − .009 = Diam. of Head
C = 0.66A − .002 = Height of Head
D = 0.173A + .015 = Width of Slot
E = ⅓C = Depth of Slot

A	B	C	D	E
.060	.0894	.0376	.025	.019
.073	.1107	.0461	.028	.023
.086	.132	.0548	.030	.027
.099	.153	.0633	.032	.032
.112	.1747	.0719	.034	.036
.125	.196	.0805	.037	.040
.138	.217	.0890	.039	.044
.151	.2386	.0976	.041	.049
.164	.2599	.1062	.043	.053
.177	.2813	.1148	.046	.057
.190	.3026	.1234	.048	.062
.216	.3452	.1405	.052	.070
.242	.3879	.1577	.057	.079
.268	.4305	.1748	.061	.087
.294	.4731	.1920	.066	.096
.320	.5158	.2092	.070	.104
.346	.5584	.2263	.075	.113
.372	.601	.2435	.079	.122
.398	.6437	.2606	.084	.130
.424	.6863	.2778	.088	.139
.450	.727	.295	.093	.147

TABLE 14 OVAL FILLISTER HEAD SCREWS

A = Diameter of Body
B = 1.64A − .009 = Diam. of Head and Rad. for Oval
C = 0.66A − .002 = Height of Side
D = 1.73A + .015 = Width of Slot
E = ½F = Depth of Slot
F = .134B + C = Height of Head



A	B	C	D	E	F
.060	.0894	.0376	.025	.025	.0496
.073	.1107	.0461	.028	.030	.0609
.086	.132	.0548	.030	.036	.0725
.099	.153	.0633	.032	.042	.0838
.112	.1747	.0719	.034	.048	.0953
.125	.196	.0805	.037	.053	.1068
.138	.217	.089	.039	.059	.1180
.151	.2386	.0976	.041	.065	.1296
.164	.2599	.1062	.043	.071	.1410
.177	.2813	.1148	.046	.076	.1524
.190	.3026	.1234	.048	.082	.1639
.216	.3452	.1405	.052	.093	.1868
.242	.3879	.1577	.057	.105	.2097
.268	.4305	.1748	.061	.116	.2325
.294	.4731	.192	.066	.128	.2554
.320	.5158	.2092	.070	.140	.2783
.346	.5584	.2263	.075	.150	.3011
.372	.601	.2435	.079	.162	.3240
.398	.6437	.2606	.084	.173	.3469
.424	.6863	.2778	.088	.185	.3698
.450	.727	.295	.093	.201	.4024

34 It is believed by your Committee that the use of the formulae and resulting tables here given will insure the practical interchangeability of the class of machine screws covered by this report.

Respectfully submitted:

WILFRED LEWIS, *Chairman.*
CHARLES C. TYLER,
HORACE K. JONES,
JOHN RIDDELL,
GEORGE R. STETSON,
GEORGE M. BOND.

PRESSURES OF LAP-WELDED STEEL TUBES

The Effects of the Distortion Due to Successive Retests on the Collapsing Pressures of 10-Inch Lap-welded Steel Tubes.[1]

By PROF. REID T. STEWART, PITTSBURG, PA.
Member of the Society

The paper to which this is a supplement gives the principal results of a very complete research on the collapsing pressures of commercial lap-welded steel tubes, the tubes when tested being in normal condition as to roundness.

2 While testing the 10-inch tubes No. 445 to 454, inclusive, the conditions were found to be such that with the apparatus in use, it was practicable to make a series of retests on each of these tubes. This was rendered possible because of the small extent of the recoil of the test apparatus which for these tubes caused but slight permanent distortion after each successive failure. Indeed this permanent distortion in some cases was so slight as to be scarcely noticeable to the eye. See Fig. 62, which is a reproduction of a photograph taken after the removal of No. 450 to 454 from the test apparatus, after completion of the first test.

SCHEME OF SUCCESSIVE RETESTS

3 The scheme followed while making these retests was as follows:

a Autographic calipering diagrams of the tubes, before insertion in the Hydraulic Test Cylinder, were made in order to determine the precise initial out-of-roundness of tube at each foot along its length. (See Transactions, The American Society of Mechanical Engineers, Volume 27, pp. 746-752.)

[1] Supplement to a paper by the author on The Collapsing Pressures of Lap-Welded Steel Tubes. See Transactions of The American Society of Mechanical Engineers, Volume 27, pp. 730-822.

To be presented at the Indianapolis, Ind., Meeting (May, 1907) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

b The tube was then inserted in the test cylinder and a fluid collapsing pressure was gradually applied as in the previous experiments, care being taken to stop the hydraulic pressure pump instantly on the gages showing that failure had occurred.

c The tube after removal from the test cylinder was carefully calipered for the purpose of determining the permanent distortion it had suffered, after which it was reinserted and the test proceeded with as before. In this way for tubes of comparatively thin walls, 10 inches outside diameter and 20 feet long, a series of decreasing collapsing pressures was had corresponding to a series of increasing departures from roundness.

TABLE OF SUCCESSIVE RETESTS ON 10-INCH TUBES

4 Table 63, showing successive retests, is an abstract from the Log of Collapsing Tests, and shows the effects of retesting No. 445

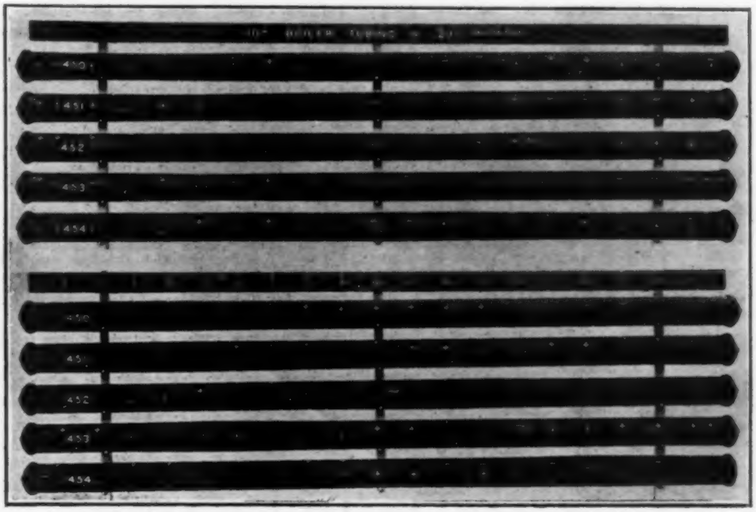


FIG. 62 FROM PHOTOGRAPH OF TESTS NO. 450, 454, SHOWING THE SLIGHT PERMANENT DISTORTION RESULTING FROM THE FIRST FAILURE OF THE TUBES. PLACE OF FAILURE INDICATED BY ARROW

to 454, inclusive, according to the scheme above indicated. The complete data relating to the first test of each of these experimental tubes will be found in the folders of Series 2, p. 787, Fig. 39, Volume 27, of the Transactions of this Society.

TABLE 63

SUCCESSIVE RETESTS ON NATIONAL TUBE COMPANY'S LAP-WELDED BESSEMER STEEL TUBES, 10 INCHES OUTSIDE DIAMETER, AND 20 FEET LONG

By R. T. Stewart, 1905

1	2	3	4	5	6	7	8
TEST NO.	RETEST NO.	COLLAPSING PRESSURE LBS. PER SQ. IN.	AFTER COLLAPSE		MAX. O.D. ÷ MIN. O.D. AT PLACE OF COLLAPSE		REMARKS
			MAX. O.D. INCHES	MIN. O.D. INCHES	BEFORE TESTING	AFTER TESTING	
445	—	210	11.18	8.67	1.024	1.289	Nominal o. d. = 10 in.
	1	87	11.37	8.42	1.289	1.350	Actual average outside
	2	82	11.44	8.34	1.350	1.372	diam. = 10.037 in.
	3	77	11.66	7.95	1.372	1.467	Average thickness of wall
	4	70	11.68	7.89	1.467	1.480	= 0.167 in.
	5	70	12.18	6.72	1.480	1.813	Plain end weight per ft. =
	6	60	12.83	5.36	1.813	2.394	17.58 lbs.
							Length of tube = 20 ft.
446	—	225	10.44	9.60	1.021	1.088	Nominal o. d. = 10 in.
	1	150	10.52	9.30	1.088	1.131	Actual average outside
	2	135	10.76	9.12	1.131	1.180	diam. = 10.031 in.
	3	115	10.83	9.00	1.180	1.203	Average thickness of wall
	4	110	10.89	8.92	1.203	1.221	= 0.167 in.
	5	105	10.96	8.80	1.221	1.245	Plain end weight per ft. =
	6	100	11.03	8.67	1.245	1.272	17.59 lbs.
	7	95	11.10	8.48	1.272	1.309	Length of tube = 20 ft.
	8	90	11.17	8.36	1.309	1.336	
	9	85	11.24	8.20	1.336	1.371	
	10	80	11.37	7.82	1.371	1.454	
	11	75	11.52	7.50	1.454	1.536	
447	—	240	10.58	9.50	1.020	1.114	Nominal o. d. = 10 in.
	1	150	10.71	9.30	1.114	1.152	Actual average outside
	2	135	10.96	8.94	1.152	1.226	diam. = 10.045 in.
	3	115	11.16	8.70	1.226	1.283	Average thickness of wall
	4	100	11.50	8.06	1.283	1.427	= 0.166 in.
	5	80	12.00	7.04	1.427	1.705	Plain end weight per ft. =
							17.50 lbs.
							Length of tube = 20 ft.
448	—	240	10.52	9.51	1.025	1.106	Nominal o. d. = 10 in.
	1	175	11.08	8.86	1.106	1.251	Actual average outside
	2	115	11.18	8.74	1.251	1.279	diam. = 10.035 in.
	3	110	11.25	8.63	1.279	1.304	Average thickness of wall
	4	105	11.33	8.55	1.304	1.325	= 0.170 in.
							Plain end weight per ft. =
							17.94 lbs.
							Length of tube = 20 ft.
449	—	210	10.60	9.48	1.023	1.118	Nominal o. d. = 10 in.
	1	135	10.70	9.31	1.118	1.149	Actual average outside
	2	120	10.82	9.11	1.149	1.188	diam. = 10.055 in.
	3	110	10.95	8.90	1.188	1.230	

TABLE 63—CONTINUED

SUCCESSIVE RETESTS ON NATIONAL TUBE COMPANY'S LAP-WELDED BESSEMER-STEEL TUBES, 10 INCHES OUTSIDE DIAMETER, AND 20 FEET LONG

1	2	3	4	5	6	7	8
TEST NO.	RETEST NO.	COLLAPSING PRESSURE LBS. PER SQ. IN.	AFTER COLLAPSE		MAX. O.D. ÷ MIN O. D. AT PLACE OF COLLAPSE		REMARKS
			MAX. O. D. INCHES	MIN. O. D. INCHES	BEFORE TESTING	AFTER TESTING	
449 Continued	4	100	11.04	8.71	1.230	1.268	Average thickness of wall = 0.157 in.
	5	90	11.16	8.57	1.268	1.302	Plain end weight per ft. = 16.55 lbs.
	6	80	11.22	8.37	1.302	1.341	Length of tube = 20 ft.
	7	75	11.31	8.18	1.341	1.383	
	8	70	11.37	8.08	1.383	1.407	
	9	65	11.88	6.70	1.407	1.773	
450	—	425	10.71	9.32	1.029	1.149	Nominal o. d. = 10 in.
	1	230	10.92	9.05	1.149	1.207	Act. ave. o. d. = 10.027 in.
	2	195	11.07	8.83	1.207	1.254	Average thickness of wall = 0.206 in.
	3	175	11.34	8.48	1.254	1.337	Plain end weight per ft. = 21.57 lbs.
	4	145	11.57	7.81	1.337	1.482	Length of tube = 20 ft.
451	—	390	10.79	9.28	1.020	1.163	Nominal o. d. = 10 in.
	1	205	10.97	9.02	1.163	1.216	Act. ave. o. d. = 10.029 in.
	2	175	11.17	8.78	1.216	1.272	Average thickness of wall = 0.194 in.
	3	150	11.52	8.41	1.272	1.370	Plain end weight per ft. = 20.35 lbs.
							Length of tube = 20 ft.
452	—	305	10.62	9.33	1.025	1.138	Nominal o. d. = 10 in.
	1	160	10.73	9.06	1.138	1.184	Act. ave. o. d. = 10.005 in.
	2	137	10.95	8.71	1.184	1.257	Average thickness of wall = 0.185 in.
	3	112	11.27	7.88	1.257	1.430	Plain end weight per ft. = 19.43 lbs.
	4	90	12.05	6.13	1.430	1.966	Length of tube = 20 ft.
453	—	395	10.75	9.25	1.024	1.162	Nominal o. d. = 10 in.
	1	200	10.95	9.03	1.162	1.213	Act. ave. o. d. = 10.033 in.
	2	170	11.15	8.77	1.213	1.271	Average thickness of wall = 0.190 in.
	3	150	11.36	8.25	1.271	1.377	Plain end weight per ft. = 19.94 lbs.
							Length of tube = 20 ft.
454	—	400	10.85	9.24	1.019	1.174	Nominal o. d. = 10 in.
	1	185	11.12	8.90	1.174	1.249	Actual average outside diam. = 10.037 in.
	2	150	11.37	8.58	1.249	1.325	Average thickness of wall = 0.195 in.
	3	125	11.75	7.94	1.325	1.480	Plain end weight per ft. = 20.54 lbs.
							Length of tube = 20 ft.

5 For convenience, however, the *principal results of the first tests* are given in the accompanying table of successive retests. For example, in this table opposite test No. 446 we read for the first test, in column three, 225 pounds per square inch as the fluid collapsing pressure; in columns four and five, 10.44 and 9.60 inches as the maximum and minimum outside diameters of the tube, at place of greatest distortion, after collapse; in column six, 1.021 as the maximum divided by the minimum outside diameter at the place of collapse before the tube was placed in the hydraulic test cylinder, and, in column seven, 1.088 as this same ratio after failure of the tube had occurred. In the "remarks" column will be found the nominal and actual average outside diameters of tube, the average thickness of wall, the plain end weight, and the length of tube between transverse joints tending to hold it to a circular form. For more complete data relating to these tubes upon the first test look for their test numbers in the above reference, folder Fig. 39.

6 The *principal results of the successive retests* are found opposite the different retest numbers given in column 2. Thus for test number 446 the first, second, and third retests show respectively collapsing pressures of 150, 135, and 115 pounds as compared with 225 pounds for the tube on its first test, or when free from distortion due to overstressing; that is to say, when the tube is normally round. Similarly the other columns of this table give for the different successive retests the values as indicated by their respective headings; thus in column 6 we find 1.09, 1.13, and 1.18 to be the maximum divided by minimum outside diameters at the place of greatest distortion before testing, for the first, second, and third retests, respectively, as compared with 1.02 for the same tube when in its original normal condition.

7 The inference is then, for this particular case, namely, experimental tube No. 446, that these collapsing pressures of 225, 150, 135, and 115 pounds correspond to differences of outside diameters at place of failure, of 2, 9, 13, and 18 per cent respectively.

CHART OF RESULTS OF SUCCESSIVE RETESTS

8 Fig. 64 shows the collapsing pressures due to the distortions caused by successive retests on the National Tube Company's lap-welded Bessemer-steel tubes, 10 inches outside diameter and 20 feet long, the retests being made on tubes of two thicknesses of wall, one averaging 0.165 and 0.196 inch.

9 It will be observed that the values of columns 3 and 6 of Table 63 are plotted on this chart to a vertical scale representing collapsing

pressure in pounds per square inch, and to a horizontal scale representing the out-of-roundness of the tube before insertion in the test cylinder, this out-of-roundness being represented by the quotient resulting from dividing the maximum by the minimum outside diameter at place of greatest distortion.

10 In this chart the crosses represent plotted values of individual experiments, while combined crosses and circles represent the different group averages of these experiments.

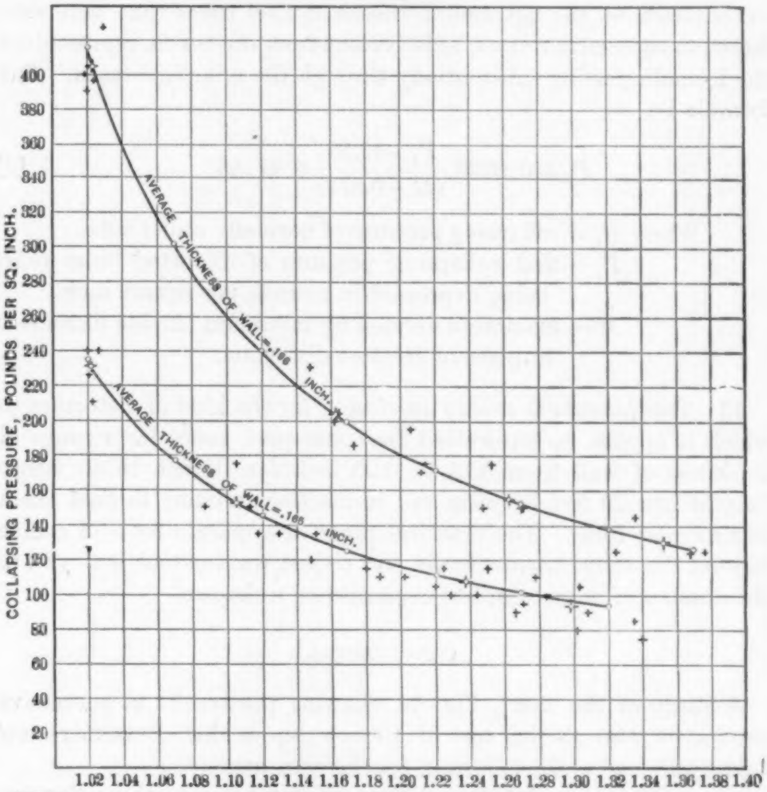


FIG. 64 CHART SHOWING COLLAPSING PRESSURES DUE TO DISTORTION CAUSED BY SUCCESSIVE RETESTS ON LAP-WELDED BESSEMER-STEEL TUBES, 10 IN. OUTSIDE DIAM. AND 20 FT. LOND.

FORMULA FOR SUCCESSIVE RETESTS ON 10-INCH TUBES

11 An empirical formula has been derived to represent the series of values plotted, namely, those corresponding to tests No. 446–454.

inclusive, omitting No. 452 as differing too much in thickness from the average of the group to which it belonged. Values calculated by means of this formula are plotted on the chart by means of the circles through which are drawn the curves that show how the collapsing pressure is related to out-of-roundness of tube caused by overstressing or thicknesses of 0.165 and 0.196 inch, for 10-inch tubes that are 20 feet long between end connections tending to hold them to a circular form.

12 This formula represents exceedingly well the results of the experiments on the lap-welded Bessemer-steel tubes that were subjected to successive retests, as is evident from the curves representing the formula passing substantially through the group averages. The formula is:

$$P_2 = 0.0926\,\frac{P_1 - 47.55}{(M - 0.874)} + 47.55 \qquad \text{[J]}$$

Where P_1 = collapsing pressure of normally round tube.
P_2 = that collapsing pressure of distorted tube both being expressed in pounds per square inch.
M = maximum divided by minimum outside diameters at place of greatest distortion.

13 This *formula is strictly applicable*, for the kind of distortion to which it applies, to lap-welded Bessemer-steel tubes for a range of thickness of wall from 0.15 to 0.20 inch for 10-inch tubes whose lengths are 20 feet between end connections tending to hold them to a circular form. The practical range of applicability is of course beyond the above narrow limits, but to just what extent is as yet, in the absence of more complete experiments, unknown.

CONCLUSIONS

A study of the chart, Fig. 64, showing the results of successive retests on two thicknesses of 10-inch lap-welded Bessemer-steel tubes, will lead to the following conclusions, namely:

a There is a definite relation existing between the collapsing pressure of a tube and its out-of-roundness, as expressed by dividing the maximum by the minimum outside diameter at place of greatest distortion. This is clearly shown by the remarkable smoothness of a curve drawn through the different group averages represented on the chart by combined circles and crosses.

b An out-of-roundness of 10 per cent, corresponding to a difference in diameter of one inch for a 10 inch tube, which is about five times that of the commercial lap-welded tube while in its normal condition as to roundness, causes a decrease in the collapsing pressure of about one-third. From this it would appear that a lap-welded steel tube when in service, if designed with an ample safety factor, of say five for ordinary conditions, could not possibly fail because of any degree of out-of-roundness that would be apt to pass ordinary inspection.

BALANCING OF PUMPING ENGINES

An Investigation as to the Proper Weight of the Plungers of a Vertical, Triple-Expansion, Crank and Flywheel Pumping Engine

By A. F. NAGLE, BUFFALO, N. Y.
Member of the Society

The above named type of engine is capable of such high thermal and mechanical efficiency that it has practically become a standard type for city use when a high duty is desirable. The calculations in this paper are made more with the view of calling attention to the possibility of producing less vibrations within the mechanism than to effect any material fuel economy, although a slight gain will be obtained by reducing the weight of the flywheels commonly used, which is possible when the plungers are properly weighted.

2 It is frequently stipulated in specifications that the steam work in the three cylinders shall be equally divided among them, but this is not possible and preserve the sizes of cylinders judged by the designing engineer to be necessary in order to produce the highest steam economy. As an illustration of the distribution of work among the three cylinders of a modern high duty engine, I have studied its steam cards taken during the duty trial, and ascertained the division of work. To carry the study a little further, I have computed the probable division of work when the load was increased 20 per cent and diminished 15 per cent. These results will be found in Table 1.

3 The cylinder dimensions were 32″, 60″, 90″ x 5′, piston rods 7½″, plungers 37″. A ratio of cylinders of 1, 3.59, 8.11.

4 If the 100 per cent of power could be taken as the more general average condition, a more even distribution of work would be obtained by making the intermediate plunger 36¼ inches, the low pressure 37¾ inches and leaving the high pressure 37 inches. Whether such refinement of proportions is justified by the circumstances must be left to the judgment of the engineer in charge.

To be presented at the Indianapolis, Ind., Meeting (May, 1907) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

TABLE 1

PERCENTAGE OF WORK IN EACH CYLINDER AT DIFFERENT LOADS

Power of engine per cent	Number of expansions	H. p. cyl. per cent	I. p. cyl. per cent	L. p. cyl. per cent
120	24	27.40	34.00	38.60
100	30	33.00	30.00	37.00
85	38	35.80	30.00	34.20
Mean		32.07	31.33	36.60

5 I wish, however, to call more especial attention to the relation between the loads, or varying heads, and the weight of the plungers—including in this term the steam pistons and all vertically moving parts.

6 If the steam valves are so adjusted as to give equal steam work on the up and down strokes, why should not the water end be so constructed that it will give equal resistance on the up and down strokes? I purpose to give the computation by which this may be accomplished.

7 The following heads on the suction and discharge may exist:

CONDITIONS OF HEADS (CENTER OF PUMP = 0)

Discharge, maximum	+212 feet
Discharge, mean	+200 feet
Discharge, minimum	+180 feet
Suction, maximum (lift)	− 12 feet
Suction, mean (pressure)	+ 10 feet
Suction, minimum (pressure)	+ 32 feet

Five extreme conditions of combined heads may be considered:

First	Maximum discharge	= 212 feet	= 91.80 pounds
	Maximum suction	= −12 feet	= −5.20 pounds
	Net head	224 feet	= 97.00 pounds.
Second	Minimum discharge	= 180 feet	= 77.94 pounds
	Maximum suction	= −12 feet	= −5.20 pounds
	Net head	192 feet	= 83.14 pounds
Third	Mean discharge	= 200 feet	= 86.60 pounds
	Mean suction	= 10 feet	= 4.33 pounds
	Net head	190 feet	= 82.27 pounds
Fourth	Maximum discharge	= 212 feet	= 91.80 pounds
	Minimum suction	= 32 feet	= 13.86 pounds
	Net head	180 feet	= 77.94 feet

Fifth	Minimum discharge	= 180 feet	=	77.94 pounds
	Minimum suction	= 32 feet	=	13.86 pounds
	Net head	148 feet	=	64.08 pounds

8 In the following calculations pounds pressure will be used in place of feet head—one foot head of water, for one square inch area, weighing 0.433 pounds.

9 The mean net pressures found in the five cases are, of course, the sums of the means of the up and down strokes, and to equalize the work each should be one-half of this. The five cases would then stand as follows:

TABLE 2

Case 1	Total net pressure = 97.00 pounds	Each stroke = 48.50 pounds
Case 2	Total net pressure = 83.14 pounds	Each stroke = 41.57 pounds
Case 3	Total net pressure = 82.27 pounds	Each stroke = 41.13 pounds
Case 4	Total net pressure = 77.94 pounds	Each stroke = 38.97 pounds
Case 5	Total net pressure = 64.08 pounds	Each stroke = 32.04 pounds

10 To obtain the actual work of the pump, the above pressures should be multiplied by the area of the plunger, but that may be neglected for the present.

11 To equalize the work on the pump end of the engine we have the water pressures (per square inch) and the weight of plunger (also represented by pressure per square inch) to consider. The latter being an unknown quantity we will call it x; the former, s plus or minus, as the suction water stands above or below the center of the plunger, and d the discharge pressure.

12 Then to equalize the up and down strokes, we should have $x \pm s$ for the up stroke equal $d - x$ on the down stroke, or

$$\left(2x = d \pm s \quad \text{or} \quad x = \frac{d \pm s}{2}\right)$$

13 Hence we have the rule, that to equalize the work on the up and down strokes, make the weight of the plunger as represented by the pressure per square inch, one-half of the *algebraic* sum of the suction and discharge pressures.

14 For the five cases taken we would then have the following results:

Case 1 $$\frac{91.80-5.20}{2}=43.30$$

To prove the correctness of this (weight) on the up stroke there would be a resistance of

$$43.30 \text{ (weight)} + 5.20 \text{ (suction)} = 48.50$$

on the down stroke there would be the discharge pressure

$$91.80 - 43.30 \text{ (weight)} = 48.50$$

Case 2 $$\frac{77.94-5.20}{2}=36.37$$

Proof, up stroke $36.37+5.20=41.57$
down stroke $77.94-36.37=41.57$

Case 3 $$\frac{86.60+4.33}{2}=45.46$$

Proof, up stroke $45.46-4.33=41.13$
down stroke $86.60-45.46=41.13$

Case 4 $$\frac{91.80+13.86}{2}=52.83$$

Proof, up stroke $52.83-13.85=38.97$
down stroke $91.80-52.83=38.97$

Case 5 $$\frac{77.94+13.86}{2}=45.90$$

Proof, up stroke $45.90-13.86=32.04$
down stroke $77.94-45.90=32.04$

15 Grouping these figures together for better comparison we have Table 3.

TABLE 3

1	2 ½ pump load per square inch	3 Balancing pressure per square inch	4 Actual weight of plunger, pounds
Case 1	48.50	43.30	46,553
Case 2	41.57	36.37	39,105
Case 3	41.13	45.46	48,878
Case 4	38.97	52.83	56,803
Case 5	32.04	45.90	49,351
Average	40.44	44.77	48,137

Column 4 is found by multiplying the pressure by the area of the 37 inch diameter, which is equal to 1075.20 square inches.

16 It is noticeable that while the net pump loads may be nearly the same as in cases 2 and 3, the balancing pressures may differ 25 per cent. Also, the pump loads may differ 50 per cent, as in cases 1 and 5, and yet the balancing pressures differ but 6 per cent.

17 If case 3 is the prevailing condition of water pressures, it is also very nearly the average of all possible conditions and a weight of plunger of 48,000 pounds is the best balancing weight that can be made.

18 There is no reason why flywheels in triple expansion pumping engines should be so very heavy. The turning moments during one revolution do not vary over 16 per cent; nor is absolutely uniform

rotative velocity of wheels necessary. With plungers weighted as described in this paper, I have no doubt but that many examples exist where the weight of the wheels could be safely reduced one-half. Since the above was written my attention has been called to an engine which is fully 50 per cent of its load out of balance, and yet its two flywheels are so heavy that no appreciable deviation from perfect rotative speed is observed

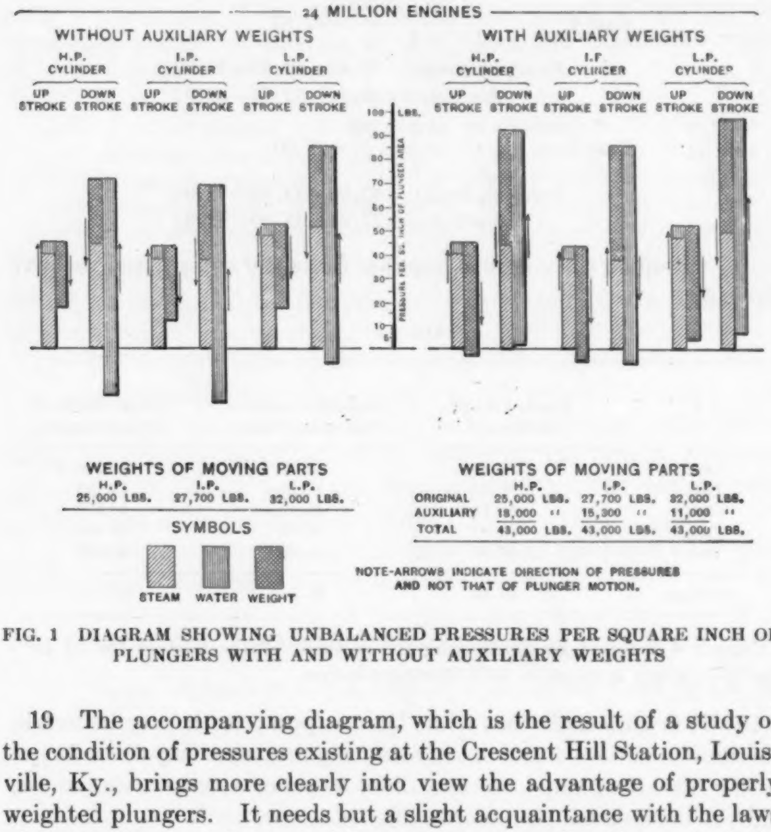


FIG. 1 DIAGRAM SHOWING UNBALANCED PRESSURES PER SQUARE INCH OF PLUNGERS WITH AND WITHOUT AUXILIARY WEIGHTS

19 The accompanying diagram, which is the result of a study of the condition of pressures existing at the Crescent Hill Station, Louisville, Ky., brings more clearly into view the advantage of properly weighted plungers. It needs but a slight acquaintance with the laws of mechanics to see how much better it is to equalize the work of the steam in the direct line of the plungers than to carry so large a proportion through the pump rods, connecting rods, cranks, and flywheels. As the natural pressure of these pumps is greatest on the down stroke, putting the long, slender, pump rods and connecting rods in compression (which is liable to produce vibrations), and balancing the plungers (as is here pointed out) will also equalize the

tension and compression stresses in these members. It will also reduce to a minimum the torsional stress in the shafts.

20 If there should be any deviation from a perfect balance, it would be better to have an excess than an insufficiency of weight, for that would produce an excess of tension stress in the long slender rods, while an insufficiency of weight would produce an excess of compression in these members.

21 I know of no reason why this type of pumping engine specification should not state the exact weight of plungers required, determined in the manner here pointed out. The data required to obtain it are better known to the city's engineer than to the contractor, and he may as well make the necessary calculations. If given, it would be a guide to the contractor as to what weight to provide for in the design of the engine, for I have known conditions of water pressures where the plungers even if made of solid iron would not provide sufficient weight.

22 I commend to the reader a careful study of the diagram, in explanation of which I am not sure that I can add anything. I have not given the data used with such fullness or accuracy as may satisfy a critical reader, but my principal purpose has been to suggest a correct method of the calculations involved, rather than to obtain absolute correctness of the resulting figures.

23 It may not be inappropriate to add to this paper the suggestion that in specifications for the type of engine here considered, within the limits of from ten to thirty million capacity, the exact diameter of plunger and length of stroke and number of revolutions per minute should be given, rather than the mean plunger speed. Especially objectionable is the form frequently used—"The engine shall deliver 20 million gallons in 24 hours when operating at a plunger speed *not exceeding* 250 feet per minute." Most contractors will estimate the cost of the engine on the basis of this upper limit of speed. The exception would be the more conservative bidder, who might deem 200 feet or 225 feet quite fast enough, and as his price would naturally be the higher, it would probably result in his defeat, although his might be the *better* bid. The safe way for the city is to be *exact* in stating what it wants, where exactness is perfectly feasible.

24 General practice seems to have limited the mean plunger speed of this type of engine from 200 feet to 250 feet per minute; and 5 feet stroke is equally common. It would be good practice, at the time of purchase, to base the capacity upon 200 feet plunger speed, for that would allow of an increase to 250 feet, when the city's growth called for more water. I have, therefore, prepared Table 4 showing the

dimensions of plungers, based upon 5 feet stroke, and 20 revolutions, which I think might be taken as a standard of dimensions for the capacities stated.

25 To illustrate, I would word the specification for a 25 million engine, as to capacity, as follows:

The engine shall have plungers 38 inches in diameter, by 5 feet stroke, making 20 revolutions per minute at its normal speed, and capable of increasing this speed to 25 revolutions per minute. While making 20 revolutions per minute, the pumps will deliver nominally 25 million gallons in 24 hours.

TABLE 4

PLUNGER DIAMETERS FOR VERTICAL, TRIPLE EXPANSION, CRANK AND FLYWHEEL PUMPING ENGINES, HAVING PLUNGERS 5 FEET STROKE, AND MAKING 20 REVOLUTIONS PER MINUTE

1 Million gallons 24 hours	2 Gallons per rev.	3 Gallons per foot	4 Theoretical diam.	5 Actual diam. inches	6 Gallons per foot	7 Deviation per cent	8 Gallons per 24 hrs. for each r. p. m.
10	347.22	23.15	23.82	24.00	23.50	+1.5	0.50 mill
12	416.66	27.77	26.09	26.25	27.58	+1.5	0.60 mill
15	520.83	34.72	29.17	29.375	34.31	+1.5	0.75 mill
20	694.44	46.30	33.69	34.00	47.16	+1.9	1.00 mill
24	833.33	55.56	36.90	37.00	55.86	+0.54	1.20 mill
25	868.05	57.87	37.68	38.00	58.92	+1.8	1.25 mill
30	1041.66	69.44	41.25	41.5	68.58	+1.5	1.50 mill

Column 8 is obtained from column 2, and if used in connection with the actual diameters given in column 5, would correspond very nearly to the actual delivery, the excess given in column 7 being no more than the least slip obtained in practice.

To obtain the gallons pumped in 24 hours multiply the counter record by column 2 for the particular engine, or divide the counter record by 1440 (minutes in 24 hours) and multiply by column 8.

USE OF SUPERHEATED STEAM IN AN INJECTOR

By STRICKLAND L. KNEASS, PHILADELPHIA, PA.
Member of the Society

In a large proportion of boiler plants it is customary to apply an injector to each boiler, either for continuous use, or to supplement or take the place of the feed pumps when temporarily out of service. Both the original cost and its up-keep are less than that of the pump, and the injector has the further advantage of always being ready for instant service.

2 The internal construction is simple, consisting essentially of a guiding nozzle for the jet of steam, a converging combining tube in which the steam impinges upon the entering water, and a diverging delivery tube to transform the energy of the combined jet into static pressure. The action of the injector is due to the transfer of the momentum of a jet of steam moving with a high velocity to a hollow cone of water, drawn into the tubes by the partial vacuum caused by condensation. The special construction of the tubes obtains intimate contact between the steam and water, and almost perfect condensation of the steam, with a reduction of the transverse area of the combined jet proportional to its increase in velocity; the resultant energy of the mass enables it to pass through the reduced area of the final tube of the apparatus and enter the boiler against initial pressure. Its action therefore depends not only upon the impact of the jet of steam, but upon its efficient and complete condensation, which occurs during its passage through the combining tube. At 180 pounds boiler pressure the jet must attain a terminal velocity of 163 feet per second to enable it to lift the check valve and enter the boiler. If the total length of the converging combining tube is 7½ inches, the interval of time during which the steam may be condensed is only 0.008 of a second and the acceleration is 20,000 feet.

3 It is therefore obvious that any condition which tends to

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diminish rapid condensation, operates against efficient mechanical action. An increase in the temperature of the water supply, moisture or superheat in the steam, all tend to reduce the proper ratio between the weight of the water delivered into the boiler, to that of the motive steam.

4 It is therefore essential that the condition of the steam permit instant and complete condensation and also that its velocity reach a maximum at the instant of impact with the water. Many experiments have been made by the writer to determine the most efficient shape of diverging steam nozzle and also the terminal velocity of the discharging jet. Results of experiments with saturated steam prove that the flow is in accord with the well known formula based upon adiabatic expansion. The velocity of superheated steam is slightly higher as it follows the law of a perfect gas until condensation, due to expansion, commences; the velocity of the combined jet would consequently be increased, but this advantage is overbalanced by the shorter interval of contact and condensation, during which the additional heat in the steam must be abstracted. The mechanical efficiency is lowered; if there is no loss from radiation, the thermo-efficiency will still be 100 per cent. To obtain good results from an injector with superheated steam, it would be necessary to modify the design and proportion of the tubes and nozzles.

5 The practical effect of superheated steam upon the action of an injector is to reduce the maximum capacity, increase the minimum capacity, and to lower the limiting temperature of the water supply with which the injector can operate. Further, with high pressure and superheat, an inefficiently designed instrument is inoperative. It is therefore advantageous and usually practicable to have a special pipe to supply the injector with saturated steam.

EXPERIENCES WITH SUPERHEATED STEAM

By GEO. H. BARRUS, BOSTON, MASS.
Member of the Society

PLANT *A*

My experiences with superheated steam date back to 1874, and they began at the Massachusetts Institute of Technology in connection with the "Dixwell" experiments. The plant on which these experiments were made consisted of an ordinary 36 inch vertical fire-box boiler set in brick work and provided with a Dutch-oven furnace, a rectangular cast iron superheater set over an independent furnace, and an 8″ x 24″ non condensing Corliss engine.

2 The superheater here proved unreliable. It cracked after a short time, and was abandoned. Later the vertical boiler was found to answer every purpose by simply carrying the water to a low point, and exposing considerable steam heating surface to the action of the products of combustion. The temperature of the steam was regulated by the activity of the fire. This apparatus proved to be a most satisfactory form of superheater. With it there was no difficulty in maintaining a temperature of 600 degrees F., and superheating all the steam that was required by the 8″ x 24″ engine.

3 The object of the Dixwell experiments was to show that the degree of superheating necessary to prevent cylinder condensation varied in direct proportion to the ratio of expansion. On the engine in question, with a ratio of expansion of 3 to 2, the number of degrees required was about 110; with a ratio of 2½ to 1, the number was increased to 146 degrees, and with a ratio of 4 to 1, it was still further increased to 190 degrees. As a telltale, indicating when the condensation in the cylinder was suppressed, a cylinder pyrometer, which was similar in outward appearance to any metallic pyrometer, was inserted through the wall of the cylinder in such a position as to lie diametrically across the cylinder just beyond the counter-bore, and a cavity was cut in the inside face of the cylinder head to make room for it. The action of this instrument proved an interesting and

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important feature of the work. When the engine was running with ordinary saturated steam, the pyrometer responded to the variations of temperature in the cylinder, and during every revolution the index hand vibrated over a range of 20 to 25 degrees of temperature. It jumped to the highest point at the beginning of the stroke when the steam was admitted, and then fell off to the lowest point during expansion and exhaust. When the steam began to be superheated, the range of vibration began to diminish, and when the temperature rose to a sufficient degree, the vibrations disappeared altogether, and the pyrometer indicated a constant temperature. The latter was slightly above the normal for the initial pressure. It is thus seen that with the 4 to 1 ratio of expansion and 190 degrees superheat at the throttle valve, there was a very large drop in temperature in the short distance between the throttle valve and the interior of the cylinder, that distance being not more than two linear feet.

4 In connection with this work, an interesting experiment was made to demonstrate to what extent the drop in temperature between the throttle valve and the cylinder was due to heat converted into work. The engine was stopped, and the four valves set wide open. Then the throttle valve was adjusted to such an opening as to discharge steam at the same rate as was consumed when the engine was running. With a ratio of expansion of 2½ to 1 and a temperature of 450 degrees at the throttle valve, the cylinder temperature was 70 degrees lower and the exhaust pipe temperature 140 degrees lower when the engine was running than when the steam was blowing through. In another case with a ratio of 3 to 2 and 410 degrees temperature at the throttle, the cylinder temperature was 45 degrees lower and the exhaust temperature 120 degrees lower with the engine running than with the steam blowing through. A comparatively small portion of the drop in temperature was therefore due to radiation losses, and a large portion to the conversion of heat into work.

PLANT *B*

5 The next experience was with a superheater of the Bulkley type, set over an independent furnace, and surmounted by a coil of wrought iron pipes. The area of exterior surface in the main superheater, which consisted of two "U" sections, was some 60 square feet, and that in the added pipes about 60 feet more, making a total of about 120 square feet. The area of grate surface was 7 square feet. This apparatus readily heated the steam made by an 80 horse power boiler, which was 75 feet away, to any temperature desired. On a

test it was found that one pound of anthracite coal, containing 15 per cent of ash and refuse, superheated 50 pounds of steam 228 degrees, besides evaporating the moisture due to condensation in the steam pipe, and whatever moisture came over from the boiler. The steam pressure was 75 pounds.

PLANT *C*

6 Another experience with a superheater of the Bulkley type was a case where the attachment was made to a horizontal return tubular boiler. The boiler was one of a plant of two, the shells of which were 48 inches in diameter and 16 feet long, used in running a 16″ x 36″ non-condensing four-valve engine. In this engine the steam valves were of the double poppet type, and the exhaust valves, plain slide valves. All the steam passed through the superheater. A test was made before and after the installation. The consumption of small anthracite coal before the application was 4.4 pounds per indicated horse power per hour. When the superheater was applied, the temperature was raised 66 degrees and the coal consumption was reduced to 4.1 pounds per indicated horse power, the saving being about 6 per cent. The superheating in this case was not sufficient to wholly prevent condensation. A cylinder pyrometer which showed a vibration of 48 degrees with saturated steam, still gave 22 degrees with the limited superheating.

7 The superheater in this case was located behind the bridge wall in the manner usually followed for this type of boiler, and the only heat to which it was exposed was that radiated downward from the products of combustion passing under the boiler shell. With a view to increasing the degree of superheating, an independent furnace was built under the superheating pipes, having fire and ash doors placed in the side wall. The grate had an area of 7 square feet. By burning 5½ pounds of coal per square foot of grate per hour the superheating was increased to 165 degrees, and the vibrations of the pyrometer were reduced to 17 degrees. Under these circumstances, a test with the superheater shut off gave a consumption of 4.21 pounds of small anthracite coal per indicated horse power per hour, and with the superheater running under the conditions noted, 4.04 pounds, the saving was 4 per cent. The decrease in evaporation per pound of coal due to the superheater was 10.2 per cent.

PLANT *D*

8 Still another experience was with a Bulkley superheater, this one being arranged in three sections, and set in an independent

furnace. The heating surface was about 90 square feet and, the grate surface about 6 square feet. It was arranged for superheating the steam used by a 21″ and 42″x 48″ compound Wolff engine. This engine had slide valves for initial steam and final exhaust, and cylindrical valves, similar to the Corliss, for the exhaust of the high pressure cylinder, which served also as the admission valves of the low pressure cylinder. The vacuum was produced by an independent steam-driven air pump and condenser 12″x16″x18″. The superheater was placed near the engine. The boilers, which were 250 feet away, were of the horizontal return tubular type. No provision was made for draining the steam pipe, and all the water condensed in the pipe, or brought over from the boilers, was reëvaporated by the superheater. The plant ran 10¾ hours per day, and, at the end of the day, the fires in both the boilers and superheater were allowed to burn out, being started again with wood in the morning. A test was made using anthracite coal, broken size. The engine developed 425 indicated horse power, and used about 8700 pounds of feed water per hour, or 20.5 pounds per indicated horse power per hour. The coal used in the superheater for the day's run of 10¾ hours was 277 pounds, or only 2 per cent as much as the coal used in the boilers. This amounted to 13,815 pounds and the total coal was at the rate of 3.02 pounds per indicated horse power per hour. It was found that the temperature of the steam coming out of the superheater was no greater than that going into it; in fact, it was a little less, showing that the only benefit derived was the reëvaporation of the water contained in the steam.

PLANT *E*

9 The next experience was with superheated steam generated by vertical tubular boilers of the Corliss rolling-pin type. Two of these were used for supplying a 23″x 60″ single cylinder Corliss non-condensing engine. The area of grate surface in each was 45 square feet; water heating surface in each, 940 square feet; and steam heating surface, 425 square feet. 90 degrees of superheat were produced with a flue temperature of 480 degrees and a rate of combustion of 11 pounds of anthracite broken coal per square foot of grate per hour. A test of the engine was made when using steam derived partly from the two boilers mentioned, and partly from a horizontal return tubular boiler producing saturated steam, the vertical boilers doing so much of the work, however, that the steam was still superheated 82 degrees. The consumption of feed water was 26.8 pounds per indicated horse power per hour. When the horizontal boiler was crowded to supply most

of the steam, and the vertical boilers supplied so little that the superheating disappeared, the consumption of feed water was increased to 29.3 pounds per indicated horse power per hour. The difference in these figures is about 9 per cent. The difference in the evaporative performance of the boilers was so much greater in favor of the horizontal boiler, that the consumpton of coal was in both cases about the same.

10 In this connection, it may be added that, in the case of four other simple engines which the writer tested, where the amount of superheating ranged from 25 to 59 degrees, with an average of 34 degrees, there was a reduction in the percentage of cylinder condensation and leakage, as compared with that found in engines using ordinary steam under similar conditions, amounting to 8 per cent.

PLANT *F*

11 The next experience was with a plant of five 64 inch vertical boilers of the Corliss "Centennial" type, having 3 inch tubes 14 feet in length, each boiler having 951 square feet of heating surface, of which 317 square feet was steam heating surface. These boilers superheated the steam 75 degrees. They supplied a 28″ x 48″ single cylinder non-condensing Corliss engine through a 12 inch pipe, 270 feet in length. The drop in temperature between the boilers and the throttle valve when the engine indicated 410 horse power was 49 degrees, so that at the engine the superheating was only 26 degrees.

12 The chief interest in this plant lay in the effect of the hot steam and hot gases on the long fire tubes. It was found on a feed water test of the plant that the engine consumed 31 pounds of steam per indicated horse power per hour, and on a leakage test the output of the boilers appeared to be at the rate of about 1500 pounds of steam per hour, or nearly 4 pounds of steam per indicated horse power per hour. The leakage was traced to the upper tube sheets where a large number of the tube ends were blowing steam. Re-rolling of these tubes overcame the leakage to a considerable extent, but did not altogether prevent it.

13 In the other vertical boilers which have been referred to, where there was an equal amount of superheating without difficulty of this kind, the length of tubes was 10 feet or less, and they were of smaller diameter.

PLANT *G*

14 The next experience was with an independently fired superheater of somewhat larger proportions than any thus far referred to.

The heating surface here was made up of 2 inch continuous wrought iron pipes which presented a total area of 2640 square feet, and the grate surface measured 32 square feet. The brick setting measured 16 feet long, 9.5 feet wide and 22.5 feet high, over all. Steam was supplied from a plant of Babcock & Wilcox horizontal water tube boilers containing 10,500 square feet of heating surface and 178 square feet of grate surface.

15 A ten-hour test was made with this superheater delivering steam at a temperature of 697 degrees F. The boiler pressure was 149 pounds giving a superheating of 337 degrees F. The weight of steam passed through was 25,982 pounds per hour. The weight of dry coal consumed was 535 pounds per hour, and this had 8 per cent ash and refuse. The calorific value of the fuel was 15,271 B.t.u. per pound of combustible. Reducing these quantities to the unit rate, one pound of dry coal superheated 49 pounds of steam 337 degrees besides evaporating whatever moisture was carried over from the boilers and condensed in the connecting pipes. It is probable that the percentage of moisture, all told, which entered with the steam was between 1 and 2 per cent.

16 A noteworthy incident of this test was the effect of the highly heated steam on the joints of the piping and on the packings and gaskets of the valves. Whenever the steam came in contact with the fibrous material or rubber, these were completely burned out, and the joints or valve stems set to profuse leaking. The flange joints in the piping, which were of the Van Stone type with corrugated copper gaskets, were injured to some extent and many of them set to leaking. The plant had previously been run at a temperature not over 550 degrees. Under this temperature there was no leaking at any point.

PLANT *H*

17 Another case of an independent superheater similar to that of the preceding plant is of interest. This was one which was used in a factory running ten hours per day, and during the remaining fourteen hours the superheater was out of active service, and the fire was banked. This superheater had 1810 square feet of heating surface and 32 square feet of grate surface. The boilers were of the horizontal water tube type.

18 A test was made covering the entire working period of twenty-four hours, and under the regular working conditions. The weight of dry New River coal consumed in the superheater was 3092 pounds, and it contained 7.9 per cent of ash and refuse. The weight of water

evaporated and passing through the superheater was 152,114 pounds. The number of degrees of superheating during the ten hours running time averaged 303 degrees, and the pressure was 136 pounds. The boiler horse power developed during running time was 389. Reducing these figures to the unit rate, one pound of dry coal superheated 49 pounds of steam 303 degrees, besides evaporating the moisture in the steam supplied by the boilers. The steam probably contained 1 per cent of moisture.

19 A Corliss compound condensing engine to which the steam from this superheater was supplied was found to consume 9.8 pounds of steam per indicated horse power per hour when the superheating at the throttle valve was 300 degrees.

PLANT *I*

20 I will refer finally to a case of superheated steam furnished by a combined water tube boiler and superheater, embracing comparative tests between such a boiler and a straight boiler of the same size and type. The grate surface was of the same area in both. The heating surface in the straight boiler had an area of 2797 square feet and this was all water heating surface. In the superheating boiler the water heating surface was 2571 square feet and the steam heating surface 595 square feet. Total, 3166 square feet.

21 The tests were made with semi-bituminous coal at, or near, the rated capacity of the respective boilers. The steam from the straight boiler contained 3/10 of 1 per cent of moisture. That from the superheating boiler was superheated 216 degrees, with a pressure of 145 pounds.

22 Making allowance for the heat represented by the superheating on the assumption that the specific heat is 0.48, the efficiency of the two outfits came out precisely the same, viz: 75 per cent of the calorific value of the fuel.

FLOW OF SUPERHEATED STEAM IN PIPES

By E. H. FOSTER, NEW YORK
Member of the Society

It is somewhat surprising that with the great number of installations which have been in practical operation there should be so little exact data available as to the flow of superheated steam in pipes. The lack of this information which is so much sought after is doubtless due to the fact that plants are usually constructed on a working basis and not for experiment. As an example, a battery of boilers all fitted with superheaters will deliver steam into a common header or equalizing pipe out of which steam will be taken at various points for the engines which are being served by the boilers. This usual condition of power plant piping permits a free exchange of surplus steam back and forth, according to the demands, and throws such a cloud of uncertainty over the actual velocities of the steam in the various pipes as to effectually thwart any attempt to get a correct accounting for the cause of any decrease in temperature or pressure. Also at various plants the insulating covering differs perceptibly both in character and thickness. Occasionally, however, a situation is found where there is a run of pipe with a known quantity of steam passing through from which data may be obtained to throw light on the laws governing the flow of steam. From quite a large number of plants we have been able to collect enough data to indicate that the laws governing the flow of superheated steam differ appreciably from those governing the flow of saturated steam. A few general conclusions have been reached as follows:

a That the rate of heat transfer per degree difference in temperature per square foot of surface per hour increases with the steam velocity.

b That this increase is more rapid in small than in large pipes.

c That the percentage loss in heat decreases with the velocity, notwithstanding the rising rate of heat transfer.

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2 A high velocity of superheated steam in pipes is therefore recommended, because there is a smaller percentage of heat losses and because there is a lower actual drop in steam temperature.

3 The data at hand, while ample to show that the above conclusions are true, have not as yet been arranged sufficiently in detail to allow a formulation of a general law. It would be necessary to have a series of tests, conducted on a large scale, and on different sizes of pipes all covered in a uniform manner, in order to establish a formula covering the actual loss of temperature and pressure by superheated steam at different velocities.

4 Our practice is to recommend for steam pipes of straight runs or easy bends a velocity of 6000 to 8000 feet per minute where a superheat of from 100 to 200 degrees F. is used, and we have found these proportions to give very satisfactory results.

5 To substantiate the foregoing conclusions, the writer offers a few curves which have been constructed from a mass of notes which have been collected from time to time; also a set of curves taken from a very exellent and complete paper read by Mr. O. Berner before the German Society of Engineers in Berlin, published in their Transactions of 1904.

6 This table is also given after being converted into English units. It is expected that these figures will be materially revised from time to time as more complete data on the various subjects are available.

TABLE 1

Loss in Temperature in Degrees F. for 100 Feet of Pipe (O. Berner)

Av. steam pressure 176.5 lbs. Av. steam temperature 482° F. 105° superheat			
DIAM. PIPE, IN.	VELOCITY OF STEAM IN FEET PER MINUTE		
	1968	3936	5904
3.937	50.3°	25.5°	16.45°
7.874	25.5°	12.7°	8.23°
11.811	17.0°	8.23°	5.49°
15.748	12.6°	6.07°	4.39°

Fig. 1 shows the rate at which the drop in temperature per hundred lineal feet of run of pipe decreases as velocity of steam increases, and is approximately correct for pipes from 6 to 10 inches in diameter.

Fig. 2 shows that the variation in rate of transfer of heat units per square foot of degree difference in temperature per hour increases almost directly with the velocity of the steam in the pipe, and varies for the different sizes of pipes and different kinds of covering. In

pipes No. 1 and 2 a good magnesia covering was used; in No. 3 Keasby Magnesia standard thickness, and in No. 4 Magnesia 1⅛ inch.

Fig. 3 is a convenient diagram to show the required cross sectional area of a pipe passing 1000 pounds of steam per hour at velocities of 6000, 8000 and 10,000 feet per minute and at different temperatures and pressures.

Fig. 4 is a curve constructed from figures given by Mr. O. Berner.

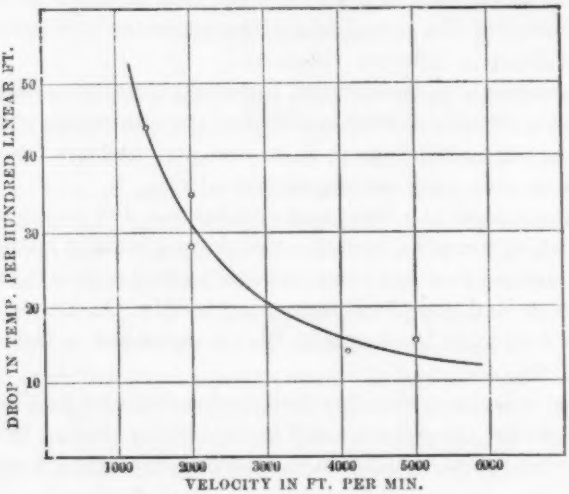

FIG. 1 VARIATION IN DROP IN TEMPERATURE IN SUPERHEATED STEAM LINES, WITH VELOCITY

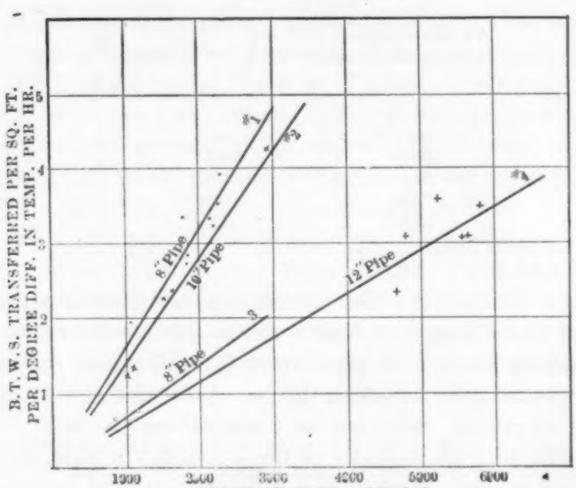

FIG. 2 VARIATION IN HEAT TRANSFER IN STEAM PIPES, WITH VELOCITY

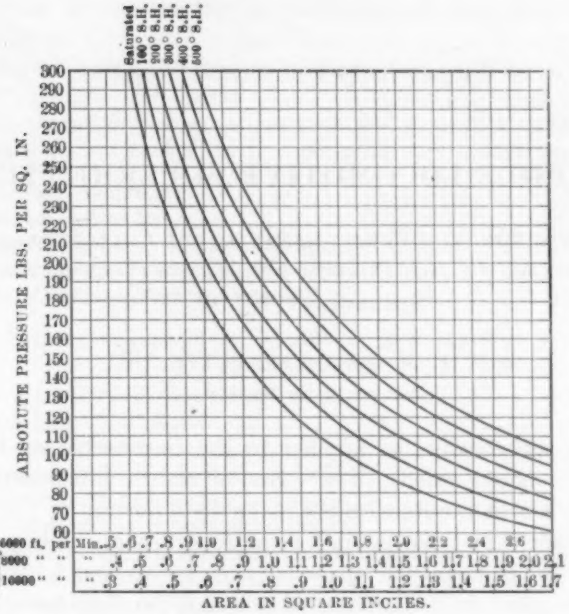

FIG. 3

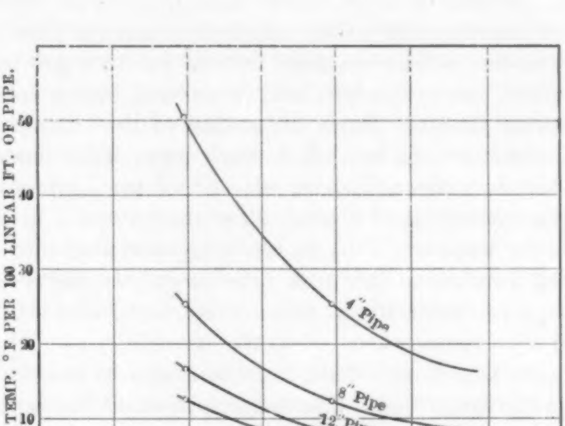

FIG. 4 LOSS OF TEMPERATURE IN SUPERHEATED STEAM LINES, VARYING WITH SIZE OF TYPE AND VELOCITY OF STEAM

THE COLE LOCOMOTIVE SUPERHEATER

Notes Concerning the Performance of the Cole Superheater as Applied to the Purdue University Locomotive, "Schnectady No. 3"

By W. F. M. GOSS, LAFAYETTE, IND.
Member of the Society

The Cole superheater, as applied to the locomotive of Purdue University, consists chiefly of a series of return tubes extending inside of certain of the flues which make up a portion of the direct heating surface. To make room for the superheater the upper central portion of the usual flue space is taken by sixteen 5 inch flues, which are reduced to a diameter of 4 inches for 7 inches of their length at the fire-box end, and increased to a diameter of $5\frac{1}{16}$ inches at the front tube sheet. They have a length between flue sheets of 138 inches. In each of these sixteen flues there is an upper and a lower line of superheating tubes. Each line extends from a steam pipe header in the smoke-box back into its flue to a point near the back tube sheet where it meets and is screwed into a return pipe fitting of special design. From the second of the two openings in this fitting, a similar pipe extends forward through the flue and into the smoke-box to a second header from which branch pipes lead to the cylinders. Altogether there are 32 of these loops. In 13 of the flues, the lower loops are $116\frac{3}{8}$ inches long extending into the flue within 2 feet 5 inches of the back tube sheet. In the other three flues, the loops are, respectively, 3 feet, 2 feet, and 1 foot shorter than the normal.

2 The upper loop in each flue is in all cases approximately 9 inches shorter than the lower loop. The headers to which the pipes of the superheater connect at the smoke-box end are of cast steel. They have walls $\frac{3}{8}$ inch thick and are cored in such manner that all steam

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passing the throttle of the locomotive must pass some one of the several loops.

3 The following dimensions and constants will be of interest:

HEATING SURFACE OF BOILER AS DESIGNED FOR SUPPLYING SATURATED STEAM PRIOR TO THE TIME WHEN IT WAS FITTED WITH A SUPERHEATER

Number of 2 inch flues	200
Length of flues, feet	11.47
Heating surface in flues fire side, square feet	1086
Heating surface in fire box, square feet	126
Total heating surface, square feet	1212

HEATING AND SUPERHEATING OF BOILERS AS NOW EQUIPPED WITH THE COLE SUPERHEATER

Number of 2 inch flues	111
Number of 5 inch flues	16
Length of flues, feet	11.47
Heating surfaces in flues, square feet	817
Heating surface in fire box, square feet	126
Total direct heating surface, square feet	943
Outside diameter of superheater tubes, inches	1¼
Number of loops	32
Average length of pipe per loop, feet	17.27
Total superheating surface based upon outside surface of tubes only. Surface of headers neglected. square feet,	193
Total heating and superheating surface, square feet	1136

4 For the purpose of observing performance, thermometers reading to 750 degrees F. were inserted in each of the two branch pipes extending between the superheater and cylinders, in the discharge side of all loops, six in number, the length of which varied from the normal, and in the upper loop of the right hand upper flue, which loop is of normal length. All thermometers were in wells thoroughly jacketed by a current of steam flowing from the stream, the temperature of which was sought.

5 The results show that the degree of superheat in the steam delivered to cylinders is largely affected by the rate of evaporation. Thus in Fig. 1 the average degree of superheat as shown by readings taken from the two branch pipes is plotted against the rate of evaporation. It shows that as the evaporation per square foot of heating surface per hour is increased from 7 pounds to 15 pounds, the degree of superheat rises from 122 degrees to 188 degrees F., due doubtless to the fact that the superheating surface, as compared with the direct heating surface, absorbs a greater portion of the total heat as the rate of evaporation increases. For all tests represented upon this diagram each pound of steam delivered received from the direct

heating surface approximately 1160 B. t. u. and from the superheating surface from 70 to 104 B. t. u. depending upon the rate of power at which the boiler was worked.

6 Another expression of the fact to which attention has already been called is well set forth by Fig. 2 which shows the per cent of the total heat taken up by the water and steam which is absorbed by the superheater, plotted in terms of smoke-box temperature. It will be seen that as the temperature of the smoke-box changes from 600 degrees F. to 800 degrees F., the heat absorbed by the superheater rises from 5.6 per cent to 8.5 per cent of the total taken up by the water and steam.

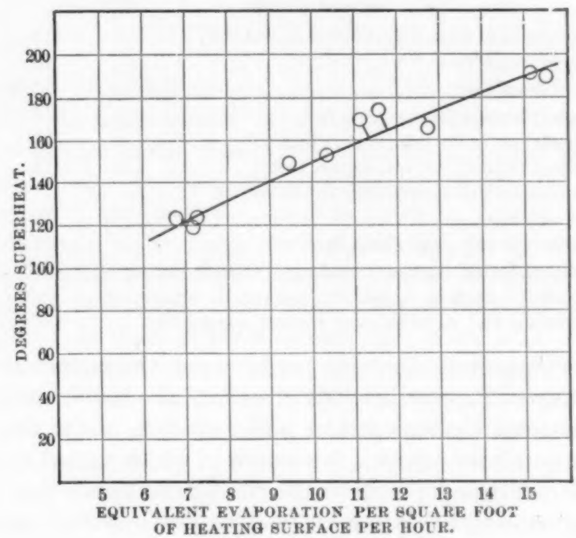

FIG. 1

7 The degree of superheating obtained from loops of different lengths is shown graphically by Fig. 3. It will be seen that the amount of superheating obtained increases rapidly as the loop is increased in length. This results from the fact that each increment in the length of the loop carries the superheating element nearer the fire-box and serves to increase the average temperature to which the whole loop is exposed. The effect therefore is twofold; first, that resulting from an increase of superheating surface, and second, that resulting from an exposure of that surface to a higher average temperature. The basis for these observations (Fig. 3) was supplied by the superheating loops arranged in three flues making up a portion of the left

hand vertical row. The lower loops in those flues were, respectively, 80 inches, 92 inches and 105 inches, while the upper loops were, respectively, 71 inches, 84 inches and 96 inches. A review of the plotted points at once discloses the fact that a higher degree of superheating is obtained from the lower loop of a given length than is possible from an upper loop of the same or even greater length. Comparing results as obtained, it appears that the lower loop in a given flue, while but a few inches longer than the upper loop, gives from 25 to 30 per cent more superheating effect. This probably is to be accepted as a

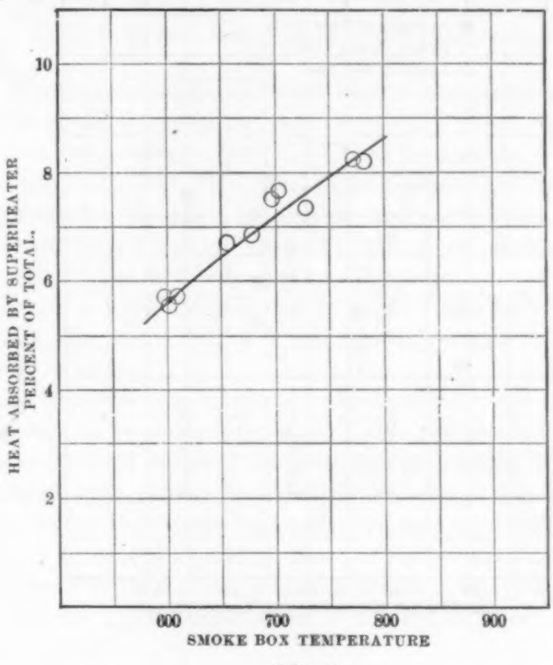

FIG. 2

measure of the advantages which come to that element of the superheating surface which is first to receive the flow of the current of moving gases, though it is not impossible that the lower loop may claim some advantages from its position in the flue.

8 It has been observed that the average temperature of the steam in the two branch pipes is always less than the calculated temperature, assuming all superheating loops to give the same performance as those which are under observation. A reason for this must be found in the difference in the volume or quality of the furnace gases transmitted by the several flues.

CYLINDER PERFORMANCE

9 While a full analysis of the cylinder performance of the locomotive must be reserved for another time, it is proper here to note that when served with saturated steam (locomotive "Schenectady No. 2"), its performance under normal condition of running was represented by a range of from 24 to 27 pounds of steam per indicated horse power hour. After being equipped with a superheater, sub-

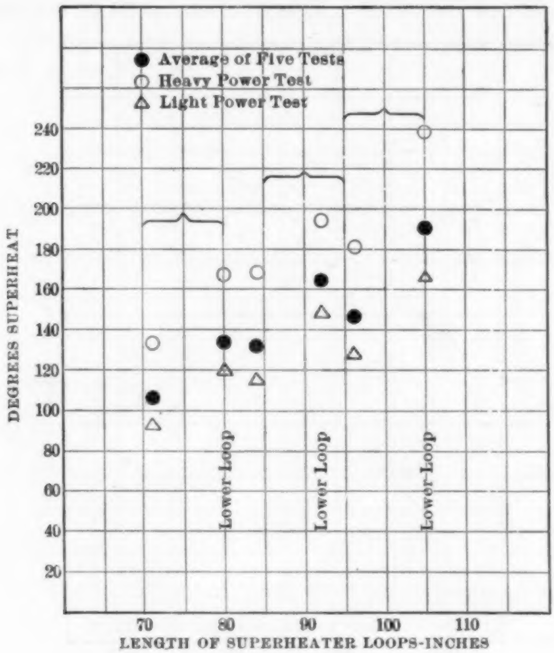

FIG. 3

stantially the same locomotive ("Schenectady No. 3") delivers under ordinary conditions of running an indicated horse power upon the consumption of from 20 to 22 pounds of superheated steam per hour, a difference of about 17 per cent.

10 The writer acknowledges indebtedness to Mr. L. E. Endsley in charge of the locomotive laboratory of Purdue University, under whose immediate direction all tests have been run.

DISCUSSION

[INDIANAPOLIS MEETING]

SPECIFIC HEAT OF SUPERHEATED STEAM

By A. R. Dodge, Published in April Proceedings

R. W. Stovel In an endeavor to answer the question "What is the most economical amount of superheat for a given condition?" I was daily becoming more puzzled as to what the specific heat of superheated steam really was when Mr. Dodge's paper came to hand.

2 Anyone who has tried to analyze and correlate a few of the researches mentioned in the Appendix will, I am sure, join me in thanking Mr. Dodge not only for his straightforward statement of what he has found the specific heat to be, but also for relegating to an appendix the many results which can only serve to shroud the subject with mystery.

3 In the hope that the method I have used to answer the question may be of service to those interested, I give my solution as follows:

4 The conditions assumed are a central generating station using large turbines with surface condensers and circulating feed water. Economizers give an average feed water temperature of 250 degrees F. and steam is generated at 215 pounds per square inch absolute. It has been decided to use superheated steam with internally fired superheaters and the question arises as to how far this superheating should be carried.

5 The total annual cost of a station for a given output is the final measure of its economy. This total cost is made up as follows:

a Interest and depreciation on first cost;
b Maintenance supplies and labor;
c Operating supplies and labor;
d Water;
e Coal.

6 That amount of superheating which makes the total of these costs the least is therefore the answer desired.

7 Granting that superheat to some extent is to be used in any case, a variation in the amount of superheat will not vary the first cost of

the station to any appreciable extent. Turbine units are selected, as to size, to meet standard capacities made by the builders, and not so close to the requirement as to be affected by slight variations in the steam rate. Nor is the ratio of boiler capacity to turbine output so closely scrutinized as to vary with small variations in the steam rate. If superheaters are used, the variation in their cost with varying amounts of superheat is negligible; hence, while there may be a tendency for the first cost to increase with the high superheats, this may be considered negligible in practice.

8 The same may also be said about maintenance supplies, and labor, namely, that while there may be a tendency to increase with the high superheats, it will be extremely difficult to find this small amount in dollars and cents.

9 The item of operating supplies and labor will not vary with varying superheat, exactly the same staff being required in any case.

10 The annual cost of make-up water will not vary with varying superheat, as while with higher superheat less water will be circulated as feed, yet the losses which the make-up water replaces will be independent of any slight variation in the turbine steam rate.

11 It will be seen, therefore, that if a variation in the amount of superheat is to effect the economy of the station it will have to do so by causing a variation in the coal bill.

12 Varying superheat affects the coal bill by varying the amount of steam required for a given output, and by varying the amount of coal required to produce a pound of steam.

13 The final measure of the effect of varying superheat on the turbine steam rate is, of course, actual test on the unit in question. As this is not available in advance of construction; we must rely on the guarantees of the turbine builders.

14 In the particular case we might have the following guarantee: "With a fixed pressure and vacuum there will be a gain of 6 per cent for 50 degrees F. superheat, 10 per cent for 100 degrees superheat, 12.5 per cent for 150 degrees superheat, and 14 per cent for 200 degrees superheat."

15 This guarantee may be expressed as in the following table.

TABLE 1

RELATIVE STEAM CONSUMPTION PER UNIT OF DELIVERED WORK WITH VARYING SUPERHEAT COMPARED WITH THE CONSUMPTION AT SATURATED STEAM AS UNITY

Saturated steam	100.0 per cent
50 degrees F. superheat	94.0 per cent
100 degrees F. superheat	90.0 per cent
150 degrees F. superheat	87.5 per cent
200 degrees F. superheat	86.0 per cent

16 The amount of heat required to produce a pound of steam with varying superheat depends on the specific heat of superheated steam at the pressures and temperatures under consideration.

17 The number of heat units required to turn a pound of water from 250 degrees F., the feed temperature, to saturated steam at 215 pounds absolute is 980.

18 We learn from Mr. Dodge that the specific heat of superheated steam at 215 pounds is 0.54, and that it does not vary with the amount of superheat that is with the temperature.

19 Hence, to the 980 heat units required for the saturated conditions we will have to add 27 heat units to superheat the pound of steam to 50 degrees; 54 heat units to bring it to 100 degrees F., and so on. This gives us the results shown in Table 2.

TABLE 2

HEAT UNITS IN A POUND OF STEAM WITH VARYING SUPERHEAT

Saturated steam	980
50 degrees F. superheat	1007
100 degrees F. superheat	1034
150 degrees F. superheat	1061
200 degrees F. superheat	1088

20 If we now make the assumption that for every heat unit taken out of the boiler in the steam a definite amount of coal is burned, that is to say that the coal efficiency of the boiler is the same whether the heat be taken out in saturated or superheated steam, then the amount of coal required to give varying superheat is in direct proportion to the amount of heat in the steam. From this we get the results shown in Table 3.

TABLE 3

RELATIVE AMOUNT OF COAL PER POUND OF STEAM WITH VARYING SUPERHEAT COMPARED WITH COAL REQUIRED AT SATURATED STEAM AS UNITY

Saturated steam	100.0 per cent
50 degrees F. superheat	102.8 per cent
100 degrees F. superheat	105.5 per cent
150 degrees F. superheat	108.3 per cent
200 degrees F. superheat	111.0 per cent

21 We now have in Table 1 the relative steam required per unit of work, and in Table 3 the relative coal required per pound of steam, each referred to the same base, namely, the condition of saturated steam, and each for the same variation in superheat. In other words, we have first what we get from each pound of steam, and second what it costs to get each pound of steam. Hence, the product of these

two relations gives us the relative amount of coal per unit of delivered work, which will tell us the amount of superheat for which we will burn least coal, and from the foregoing this is the amount of superheat which will give the most economical result for the station as a whole to be obtained by varying the superheat.

21 The product of Tables 1 and 3 gives Table 4.

TABLE 4

Relative Amount of Coal per Unit of Delivered Work with Varying Superheat

Saturated steam	100.0 per cent
50 degrees F. superheat	96.6 per cent
100 degrees F. superheat	95.0 per cent
150 degrees F. superheat	94.7 per cent
200 degrees F. superheat	95.5 per cent

22 From this it will be seen that maximum economy due to the use of superheated steam is obtained with about 150 degrees F. of superheat and that the economy is practically the same between the limits of 100 and 200 degrees.

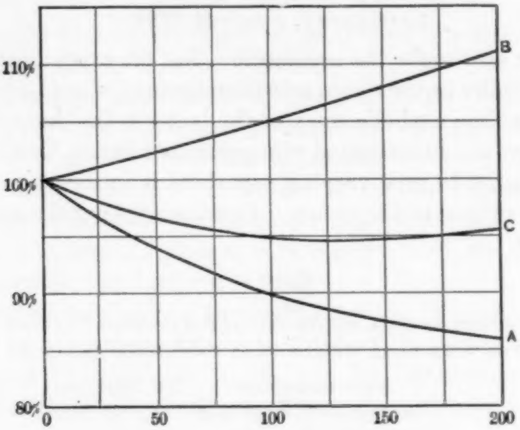

FIG. 1 AMOUNT OF SUPERHEAT IN DEGREES FAHRENHEIT.

A Relative Steam Consumption Per Unit of Delivered Work with Varying Superheat.

B Relative Coal Consumption Per Unit of Steam with Varying Superheat.

C Resulting Relative Coal Consumption Per Unit of Delivered Work with Varying Superheat.

23 Tables 1, 3 and 4 are shown graphically in Fig. 1.

24 While for the sake of clearness I have described the method at length, the same operation for any other feed temperature, boiler

pressure, specific heat and prime mover guarantee can be performed in a few minutes.

25 It is seen that in this case the maximum saving effected by superheat is about 5 per cent of the coal bill and hence if the coal cost is half the total annual cost, the maximum saving due to the use of superheat will not exceed 2.5 per cent.

26 As the saving at 100 degrees superheat is more, if anything, than at 200 degrees, and as the tendency of first cost and maintenance cost is to increase with high superheats, the point of design should be toward the lower limit of the straight part of the economy curve rather than the higher.

27 It is a well known fact that the actual saving in steam consumption due to superheat at first increases much more rapidly than in direct proportion to the savings on the ideal cycle, and it might be noted that if the relative steam consumption on the ideal cycle were used instead of the makers' guarantees in Table 1 the use of superheat would actually increase the amount of coal required for all amounts of superheat.

28 If, with apologies to Mr. Dodge, we were to assume the specific heat of superheated steam higher than the value taken, maximum economy would be given by a smaller amount of superheat, and if the actual performance of the turbine did not show the guaranteed improvements with increasing superheat, the same modification would result. Conversely, of course, lower specific heats and better turbine improvement with superheat would result in the greatest saving being obtained at higher amounts of superheat.

29 It may also be noted that the lower the feed temperature, the more heat units are required to bring one pound of water to saturated steam, hence relatively less heat units are required for the same amounts of superheat. In other words, the less economical the boiler plant as a whole is, without superheat, the greater will be the advantages of superheat

30 Similarly, in general, the less economical the prime mover is without superheat the greater will be the advantages derived from superheat, but this of course is covered by the builders' guarantee as to the effect of varying superheat.

31 In general, I believe that with normally designed stations between 2 and 3 per cent of the annual cost can be saved by the use of superheat, and that in advance of determinations for each case it is as probable that this will be done by 100 degrees of superheat as by 200 degrees.

[NEW YORK MEETING]

OUR PRESENT WEIGHTS AND MEASURES AND THE METRIC SYSTEM

BY HENRY R. TOWNE, PUBLISHED IN NOVEMBER PROCEEDINGS

MR. F. J. MILLER I have regretted that a little more attention was not paid by Mr. Towne and perhaps some others, to the work of a committee that was appointed by this Society to consider the whole subject of the metric system, and to make a report on it. Before reading a small portion of that report I wish to say that I can speak in the highest terms of the conduct of the committee which prepared it. Our relations with each other were entirely pleasant. We discussed things in a calm and judicial manner at all of our meetings, and I think all the members gave their best attention to the subject. The chairman of the committee was Mr. James Christie, and the other members besides myself were Mr. William Kent and Mr. George Bond. Following is the introduction to the report which I had the honor to write, and which was signed by all the members of the committee after considerable discussion.

1 Legislation designed to compel the exclusive use of the metric system is not desirable.

2 We believe that such legislation could not be enforced in any event so far as transactions between private individuals are concerned.

3 The general government has the power to specify the system to be used in its own work and business, and can require that work done for it by contractors shall conform to any specified measurements or weights.

4 The government cannot compel any one to bid upon its specifications.

5 Recognizing the well settled fact that the consumer does and must pay all necessary costs of production, we believe that if the government specifies such dimensions as will materially increase costs of production, the government and not the bidder will have to pay such increased costs, it being self-evident that a a bidder, not compelled to bid, will not bid except at a price which will afford him a profit.

6 The bill now before Congress is intended to make the use of the metric system compulsory in the several departments of the government, but it cannot make it compulsory in private transactions.

7 We believe there is no force in that class of arguments which consists in taking integral dimensions in one system, translating them into equivalent and therefore fractional dimensions in the other system and then making comparisons. Such arguments can be made as strong for the one system as for the other.

Although in oral discussion, perhaps at times a little heated, some members of the committee may advance arguments or make statements not in accordance with what I have just read, yet it is to be

noted that at a time when calmness of mind and deliberation prevailed, this statement of general principles was agreed to and signed by every member of the committee. I believe this statement so signed will stand the most rigid examination and that any argument, by whomsoever put forth, not in accordance with the principles here laid down is fallacious.

A PLAN TO PROVIDE FOR A SUPPLY OF SKILLED WORKMEN

By M. W. Alexander, Published in November Supplement

Prof. C. R. Richards I am very glad to have an opportunity of discussing the paper of my friend Mr. Alexander, because in the first place it seems to me such an important contribution to the problem of providing skilled workmen in mechanical industries.

2 Mr. Higgins' paper of seven years ago developed a remarkable and interesting discussion. In Mr. Alexander's paper there may be perhaps less to discuss, but if this is true it is only because it represents seven additional years of study and progress and deals largely with concrete results rather than a suggested plan.

3 The significant heart and center of the plan here described, it seems to me, is to be found in the separate equipment and provision for instruction independent of the commercial practice of the shop.

4 It has come in my way during the past few years to examine either directly or through the reports of others the workings of over thirty apprenticeship systems in various manufacturing establishments. The best of these systems places the apprentice under the care of a foreman who is responsible for his instruction during the entire course of the apprenticeship, and although it is very true that good work is being accomplished by this method and some very competent men being turned out, it seems to me that the plan described by Mr. Alexander is a very important step in advance.

5 The inherent weakness of any scheme of training workmen in the regular conduct of a shop lies in the fact that a shop organization is established for production and not for instruction and consequently any attempt at instruction not only entails a certain economic loss, but, from the nature of the case, can never reach a maximum of efficiency.

6 For these reasons the provision of a separate equipment, as described in this plan, for purposes of instruction and of separate

instructors whose sole business it is to teach the learner, makes for results that are practically impossible under any supervising system.

7 It may be said that the possibility of such a plan is limited to the establishments of large manufacturing corporations; and this may be true, but in the first place it should be noted that there are a great many large corporate manufacturing establishments in the field today requiring highly skilled workmen, and there are liable to be more. How far it is practicable to extend this system of training to smaller establishments it is hard to say and this can be determined only by experiment.

8 When Mr. Alexander passes from the definite account of what has been done in a commercial establishment to what may be done by a school independent of any commercial establishment we are on much less certain ground.

9 Here we cut loose for certain tremendous advantages presented by the shop school and face some extremely difficult and as yet unsolved problems. These are almost wholly of an economic character: first is the problem on the side of the learner who is put to the expense of losing a steady though small income, and second, the problem of maintenance of the school.

10 In the shop school the product contributes to the total production of the establishment, and for this reason it is possible to defray part or whole of the expenses of maintenance and to pay good apprentice wages to the learners.

11 Mr. Alexander suggests that the school can provide for the design and manufacture of an easily salable article and that able business management may overcome certain difficulties. If able business management can solve these economic difficulties and make a school shop pay for its maintenance and return a wage to the learner it will have gone far to solve the whole problem of industrial training. As yet, however, the practicability of such a proposition remains to be demonstrated.

12 The demonstrated fact that is so clearly brought out in the paper is that a remarkably efficient system for training skilled workmen has been developed in a commercial establishment through making provision for instructions separate from the regular shop organization.

BOILER AND SETTING

By A. Bement, Published in November Proceedings

Mr. Embury McLean It may be of interest to the members of the Society to know that a combination of forced and induced draft, substantially as described in Mr. Bement's paper, has been applied and thoroughly tested for several years in hundreds of boilers and that the term "Balanced Draft" has been used as the commercial name of the system. The tests made under the well-known A. S. M. E. code of rules and often by prominent members of the Society have almost invariably shown increased boiler efficiency, increased boiler capacity, and the ability to maintain the boiler duty while burning the cheapest grades of fuel, resulting, of course, in marked economy. A table showing the increase in economy and capacity effected by the installation of balanced draft in several representative steam plants is here given. This list includes the plant of the Flatiron building in New York to which Mr. A. J. Herschmann referred in the discussion of Mr. Bement's "Notes on Efficiency of Steam Generating Apparatus," presented at the Scranton meeting in June of 1905.

2 Balanced draft differs from all other systems of combustion in that the amount of air supplied to or entering the furnace is limited to the amount required to burn the coal. The air supplied to a furnace by a chimney is an uncertain quantity, varying with the thickness of the bed of fuel, with the opening of the fire door, and with atmospheric conditions. Therefore, in order to attain accurate control of the air supply, it is necessary to eliminate chimney draft as a factor by balancing the draft.

3 The draft is balanced by throttling the suction of the chimney in relative ratio to the speed of a special type of fan-blower which supplies air to the ashpit, so that atmospheric pressure is maintained in the furnace chamber. The speed of the fan-blower is controlled by the boiler pressure, and the position of the damper varies in unison with the variations in speed of the blower, being controlled either by steam pressure actuating the blower engine, or by the pressure of the gases in the furnace chamber. The fan blower is so designed that it will deliver approximately a constant volume of air of variable pressure for any given speed. The volume varies with the speed and the pressure varies with the resistance. The pressure in the ashpit, therefore, varies with the thickness of the fuel bed, and the volume of air varies in accordance with the demands for steam made upon the boiler and is limited to the minimum amount of air required to maintain the necessary rate of combustion.

4 Balanced draft increases both the capacity and efficiency of the boiler and furnace:

a. By attaining the highest possible temperature of the gases of combustion. When the supply of air has reached the proper amount for perfect combustion, *viz:* approximately, 12 pounds of air to each pound of coal, the furnace is developing its maximum temperature. Any excess of air beyond this amount will reduce the temperature of the furnace by diluting the gases with the air that does not combine with the coal. As the boiler absorbs heat in proportion to the difference of temperature between the gases and the boiler, maximum temperature of furnace gases gives the maximum rate of absorption of heat by the boiler.

b By increasing the time of contact of the gases with the heating surface. As the volume of gases generated is reduced to a minimum for a given quantity of coal burned, the velocity of their travel through the boiler can be proportionately reduced. As time is an element in the absorption of heat by the boiler, the greater the time the gases are in contact with it, due to the reduced velocity, the greater the proportion of heat in the gases absorbed by the boiler.

c By increasing the effective heating surface. The reduced velocity of the gases and their even distribution and diffusion to all parts of the heating surface makes every inch effective instead of having a considerable portion of the heating surface pocketed, or out of the direct line of travel of the gases from the edge of one baffle to the next.

The capacity is further increased by the possibility of effectively burning a greater amount of coal. As the volume of gases from a given quantity of coal burned is reduced by the exclusion of excess air, the quantity of coal effectively burned in a given time can be proportionately increased.

5 Aside from the exhaustive evaporation tests, the results of some of which are given, the above statements are confirmed by the increased percentage of CO_2 in the flue, demonstrating a great reduction in volume in flue gases, and a like reduction of heat units here wasted; also by the reduced flue temperature.

6 Analysis of the flue gases from a furnace operated by either forced draft, induced draft, or chimney draft, will rarely show an average amount of CO_2 greater than 8 per cent, while with balanced

draft an average result of at least 16 per cent of CO_2 is usually obtained. The increased percentage of CO_2 alone proves that balanced draft reduces the air supplied to the furnace to practically the theoretical amount required for perfect combustion, and that with forced draft, or induced draft, or chimney draft, about 100 per cent more air than is required is passed through the furnace.

7 That only one half the ordinary amount of gases have to be carried away has been demonstrated in a most practical manner in one prominent plant where before its installation additional stack capacity had been ordered.) The use of the system led to the canceling of the order and the abandoning and dismantling of one half the stack capacity already installed. It is a fact beyond question that the balanced draft system will double the horse power capacity of the stack. Balanced draft reduces the function of the stack to merely that of removing the gaseous products of combustion from the furnace.

8 In a boiler of the Babcock and Wilcox type, about 80 per cent of the total evaporation is effected in the tube surfaces between the front headers and the first set of baffle plates at the bridge wall. A boiler of this type can be operated with the balanced draft system without baffle plates, without reducing the efficiency, and with a large increase in the evaporating capacity. In other words, a boiler so equipped would evaporate between 6 and 7 pounds of water per square foot of heating surface at substantially the same efficiency that it now evaporates 3.4 pounds of water when operated at its present rated capacity.

9 Nor are increased capacity and economy the only advantages resulting from such a condition. The life of the boiler is greatly increased and the expense of maintenance and repairs reduced because there are no sudden changes in temperature due to the inrush of cold air when the fire door is opened. The strains due to unequal expansion and contraction and the disintegration of the furnace lining caused by these sudden changes of temperature are avoided. The deposit of scale is distributed more evenly over the entire heating surface, instead of accumulating in the bottom row of tubes, which, incidentally, is conclusive evidence that the ordinarily ineffective portions of the boiler are made effective. The time between boiler cleanings can be doubled with safety, reducing the maintenance expense and the time the boiler is out of service.

10 While balanced draft accomplishes so much in regard to capacity, economy, and generally improved boiler room conditions, it does not eliminate the smoke nuisance. As is well known and has been

TABLE I

THE INCREASE IN ECONOMY AND CAPACITY EFFECTED BY THE INSTALLATION OF BALANCED DRAFT IN REPRESENTATIVE STEAM PLANTS

NAME OF FIRM	KIND OF DRAFT	DATE OF TEST	HOURS DURATION	TYPE OF BOILERS	RATED H. P	H. P. DEVELOPED	INCREASED CAPACITY WITH BALANCED DRAFT	KIND OF COAL USED	COST OF COAL PER TON	POUNDS COAL CONSUMED	WATER EVAPORATED FROM AND AT 212° F.	WATER EVAPORATED PER LB. DRY COAL	WATER EVAPORATED PER LB. COMBUSTIBLE	COST OF 1000 H. P. PER HOUR	SAVING EFFECTED
							Per cent		Dollars	Pounds.	Pounds.	Pounds.	Pounds.	Dollars	Per cent
Standard Oil Co., Bay-	Forced	2 tests	‡8	W. T.	250	275		Rice		10,433	76,092	7.29	9.35		
onne, N. J.	Balanced	2 tests	‡8	W. T.	250	302	10.0	Rice		8,797	75,798	8.59	10.38		15.2
American Smltg. and Rt.	Forced	Dec. 13, '04	20	W. T.	500	505		Rice	1.75	47,282	348,145	7.35	9.22	4.10	
Co., Perth Amboy, N.J.	Balanced	May 26, '05	10	W. T.	500	769	52.3	Rice	1.75	23,207	214,134	9.20	10.63	3.28	20.0
Baldwin Locomotive	Natural	3 tests	9	W. T.	600	587		Soft	2.70	21,114	182,071	8.62	9.71	4.82	
Works, Philadelphia,	Balanced	3 tests	9	W. T.	600	634	8.0	Buck	2.25	23,583	196,792	8.24	9.77	4.21	12.6
Pa.	Balanced	3 tests	9	W. T.	600	643	9.5	Rice	1.75	21,978	200,294	9.10	10.67	2.97	38.4
	Balanced	1 test	9	W. T.	600	799	36.1	Buck	2.25	28,177	247,946	8.80	10.29	3.94	18.3
Albany Water Works,	Steam Jet	Nov. 14, '05	8	H. R. T.	340	356		Rice	2.07	14,721	107,055	7.27	8.03	5.26	
Albany, N. Y.	Balanced	Dec. 5, '05	8	H. R. T.	340	420	18.0	Rice	2.07	12,479	118,250	9.46	11.57	3.79	28.0
	Balanced	Dec. 6, '05	6	H. R. T.	340	481	35.0	Rice	2.07	9,979	102,008	10.22	11.71	3.52	33.0
Hudson R. El. Power Co.,	Natural	Jan. 5, '06	10	W. T.	488	371		Mix*	2.56	14,220	107,204	9.01	9.91	4.37	
Utica, N. Y.	Balanced	Jan. 13, '06	10	W. T.	488	617	66.3	Mix†	2.13	22,232	212,715	9.57	11.20	3.43	21.5
Pratt & Whitney, Hart-	Natural	Sep. 18, '06	9½	W. T.	300	270		Soft	3.80	9.556	88,523	9.26	9.81	6.51	
ford Conn.	Balanced	Sep. 19, '06	9	W. T.	300	345	27.0	Soft	3.80	10,214	107,269	10.50	11.13	5.81	10.7
	Balanced	Sep. 20, '06	9½	W. T.	300	273		No. 3 B	2.30	9,148	89,489	9.78	11.13	3.84	41.0

American Locomotive Co. Paterson, N. J.	Natural	5 tests	§60	W. T.	300	275		Soft	2.98	63,885	569,922	8.93		5.15	
	Balanced	5 tests	§57	W. T.	300	308	12.0	Rice	2.00	70,040	606,202	8.65		3.56	30.8
	Balanced	Sep. 26, '06	10	W. T.	300	369	34.0	Rice	2.00	14,417	127,275	8.83		3.48	32.4
Perth Amboy Chem. Co., Perth Amboy, N. J.	Natural	Dec. 18, '05	6	W. T.	120	124		Pea	2.80	3,750	25,623	6.83	8.15	7.10	
	Balanced	Jan. 10, '06	6	W. T.	120	185	49.0	Buck	2.20	3,956	38,294	9.57	11.80	3.96	44.0
Broad Exchange Bldg., New York.	Natural	2 tests	8	W. T.	350	317		Buck	3.50	20,250	153,134	7.50	9.00	7.19	
	Balanced	2 tests	8	W. T.	350	310		Rice	2.50	21,250	148,818	7.00	8.34	5.50	23.5
Bement, Miles & Co., Philadelphia, Pa.	Natural	Oct. 16, '05	8	W. T.	135	132		Soft	2.70	4,104	31,809	7.75	8.83	5.37	
	Balanced	Oct. 17, '05	8	W. T.	135	195	47.7	Rice	1.75	6,032	47,260	7.83	9.16	3.45	35.0
Land Title and Trust Bldg., Philadelphia, Pa.	Natural	Sep. 14, '05	10	W. T.	231	226		Buck	2.90	9,216	78,022	8.46	10.80	5.65	
	Balanced	Sep. 10, '05	10	W. T.	231	259	14.6	Rice	2.32	9,827	89,304	9.09	10.99	4.11	25.75
Strawbridge & Clothier, Philadelphia, Pa.	Natural	July 25, '05	8	W. T.	190	209.4		Buck	3.25	6,092	57,799	9.49	11.23	5.27	
	Balanced	Aug. 2, '05	8	W. T.	190	227.4	8.59	Rice	2.25	6,881	62,759	9.09	10.96	3.81	27.2
Haverford College, Haverford, Pa.	Natural	Nov. 8, '05	8	W. T.	150	90		Buck	2.65	3,509	24,860	7.09	9.64	5.76	
	Balanced	Nov. 9, '05	8	W. T.	150	152	68.0	Rice	2.15	4,943	42,379	8.55	10.78	3.87	32.7
Flatiron Building, New York.	Natural	Sep. 20, '04	12	W. T.	340	267		Soft	4.00	10,440	102,065	9.77	10.60	6.40	
	Balanced	May 2, '05	10	W. T.	340	383	43.4	Rice	2.68	12,520	120,400	9.61	11.25	4.20	34.3
	Balanced	May 9, '05	10	W. T.	300	388	43.8	Soft	4.00	11,606	133,622	11.50	12.10	5.33	16.7
Mutual Life Ins. Bldg., New York.	Natural	Aug. 14, '05	9	W. T.	300	139		Brkn	4.95	4,643	43,080	9.28	11.21	8.20	
	Balanced	Aug. 16, '05	9	W. T.	150	167	20.1	Buck	3.25	5,130	51,820	10.10	11.95	4.95	39.6
Fidelity Mutual Life Bldg. Philadelphia, Pa.	Natural	Mar. 12, '05	9	W. T.	200	183		Buck	3.75	7,366	63,150	8.56	10.82	7.05	
	Balanced	Mar. 11, '05	9	W. T.	200	217	18.6	Rice	2.75	7,776	75,000	9.63	12.35	4.60	33.8

* A mixture of 30 per cent screenings and 70 per cent soft coal
† A mixture of 84 per cent screenings and 16 per cent slack
‡ Hours each
§ Total time of 5 tests

emphasized by the discussion at Scranton, there are three important conditions necessary for complete combustion and smokeless stack:

a Proper air supply

b Proper temperature

c Proper mixture of the air and the gases

11 Balanced draft accomplishes the first two and Mr. Bement has described an effective method of accomplishing the third requisite by passing the gases under a long refractory tile roof fastened to the bottom tubes of the boiler. This combination, as he says, produces a "smoke proof" furnace.

PROFESSOR KENT I find here Mr. Embury McLean's discussion on balanced draft, I do not think it is a fair test to take an ordinary boiler and get a very low result, far below what one ought to get with that boiler in the usual conditions of everyday practice, and then publish that result in comparison with a fairly good result obtained from the same boiler when fitted with some patented appliance, claiming that the apparent saving in fuel is due to the use of the appliance. It is not a fair statement of the difference between the results "before and after taking," as you might say. I once had to make a test with an appliance and on the face of the returns, there appeared to be 20 per cent better economy as compared with the test without the appliance, but in the latter the results were very bad. I reported that the results of our tests showed nothing except that they should be repeated, and that just as good results as we had obtained with the appliance had often been obtained in an ordinary boiler, the same as the one used in these tests, a return tubular, with the same coal, without any patent device of any kind.

MR. EMBURY MCLEAN Attention has been called by Professor Kent to a tabulated statement of tests showing improved results effected by balanced drafts and the criticism has been made that the comparisons were based on conditions before the application of balanced draft, which were not normal. I wish to say that in every one of these tests the conditions were exactly the same in the tests made before the balanced draft was introduced, as after, and many of these tests have been made by members of this Society in accordance with the code of rules prescribed by this Society, so that I think the results are reliable and worthy of note. I might also call attention to the fact that many of these savings are very high, amounting sometimes to 40 per cent. No claim is made that these great savings are due entirely to increased boiler efficiency effected by balanced

draft. They are commercial results and are largely due to the fact that with the balanced draft system a much cheaper grade of coal could be used than was otherwise possible and still maintain the boiler duty. The results of the tests show with great uniformity an increase of horse power capacity of the boiler, increase of boiler efficiency, and the ability to burn the cheapest grades of fuel economically.

Professor Jacobus In the April Proceedings, Mr. Bement replies to my discussion of his paper on Boiler and Setting, and contradicts my statements regarding maintenance of brickwork and also the reduction in draft which I stated would take place if the gases were made to flow through five cross passes, as represented in his Fig. 1, p. 246, instead of through three cross passes, as are ordinarily employed by the Babock & Wilcox Company.

2 Mr. Bement says that experience (presumably his own) covering six or more years, has demonstrated that my opinion regarding the cost of maintenance of brickwork has no foundation in fact and that the reduction of draft, which I believe to exist, does not occur. It might be noted that experience extending over even six years perhaps does not cover the entire field, and it may be that certain facts are still unknown to Mr. Bement.

3 It is a fact, whether Mr. Bement believes it to be so or not, that highly heated brickwork deteriorates and that the cost of maintenance must be considered in designing a furnace. And that there is a loss of draft in contracting the cross sectional area of the passes and in making a greater number of turns in the path traveled by the gases will be appreciated by those having had experience in such matters. Perhaps Mr. Bement has inferred that I dispute the well known value of a long pass for the gases in order to increase the efficiency of the combustion and reduce the smoke, and oppose his ideas in this line, but if he will again read my discussion, he will see that such is not the case.

4 Mr. Bement also says that he is sure I have not seen any of the plants in the West which I say produce no smoke. In this he is also in error. I find, however, that my statement that "with a chain grate stoker there is no smoke" is much broader than I should have made it, for at the very time of presenting the discussion, I was working on a problem to eliminate smoke with such a device. What I should have said is, that with a chain grate stoker there may be and in many cases there is no smoke.

VENTILATION OF THE BOSTON SUBWAY

By H. A. Carson, Published in October Proceedings

The Author The ventilating duct in the harbor portion of the East Boston tunnel was made inside the tunnel cross section because a large saving in cost could thereby be made—much more than enough to balance the loss due to the reduced cross section.

2 The cross section after reduction is for each track less than one per cent smaller than much of the New York subway, less than five per cent smaller than the usual Paris and Boston subways, and is far larger than most of the electric subways of Europe.

3 The author had the experience of riding through the Pracchia tunnel in Italy both before and after its ventilation by Saccardo and greatly admires this system and its later applications in this country. There would be some objections, however, to its use in the East Boston tunnel; one being that a station may be arranged west of the easterly portal, not far from the railroad and steamboat stations. In this case the ejected air would have to be blown through the tunnel station.

4 In the 4½ miles of the Boston subway system there are 3 two-track portals and 2 for four tracks, 39 stairway openings averaging about 12 feet wide, 14 generous openings from fan chambers, and some other openings, all to the outer atmosphere.

5 It is not surprising that in breezy weather there are often currents in portions of the subway much greater than can be controlled by the present motors and fans. Observation shows that in each section of the subway the air would frequently be nearly still (except for the movement of the cars and fans) and that at times the air in all portions would be nearly still. The more rapid the currents are the the less need there is for mechanical ventilation, and when the air is still, fans of the capacity planned for the subway can effect reasonable ventilation. There would be no objection of course, except cost, to more powerful fans, limited only by the comfort of the passengers on the station platforms. Passengers generally seem to prefer vitiated air rather than draughts, and doors and windows of stairway approaches are often closed when as far as ventilation is concerned they would better be kept open.

6 The cars moving in one direction in any particular piece of the subway during operating hours are separated by brief intervals of time and there are as many moving say to the right as there are to the left. This tends to thoroughly mix the air but does not tend as a whole to either aid or hinder the fans.

7 It must be admitted, as Mr. Churchill and Dr. Soper note, that little information is given in the paper as to the quality of air in the subway. The paper was hastily prepared in response to frequent requests from the Society and all the available analyses of subway air were given. The air in the subway was rarely or never complained of, so far as the author knows, and was sometimes praised, and the matter of adding to the half dozen analyses made seven years ago was apparently not thought of. He is not aware that he based on these analyses any "deductions of far reaching importance." It was merely intended to note that the analyses, as far as they went, tended to justify the omission of ventilating fans.